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GEOLOGICAL SURVEY OF CANADA
A. P. LOW, DEPUTY HEAD AND DIRECTOR

SECOND EDITION

OF A

REPORT

ON THE

GEOLOGY AND NATURAL RESOURCES

OF THE AREA INCLUDED BY THE

NIPISSING AND TIMISKAMING MAP-SHEETS

COMPRISING PORTIONS OF THE

DISTRICT OF NIPISSING, ONTARIO

AND OF THE

COUNTY OF PONTIAC, QUEBEC

BY

ALFRED ERNEST BARLOW, M.A.

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A. P. Low, Esq.,
Director, Geological Survey of Canada.

Sir,—I beg to transmit herewith the second edition of my report on the geology, physical features and natural resources of the region in the vicinity of Lakes Nipissing and Timiskaming, comprising portions of the district of Nipissing, Ontario, and the county of Pontiac, Quebec. The report is accompanied by two maps, each on a scale of four miles to one inch, constituting sheets Nos. 130 and 138, respectively, of the Ontario series of geological maps.

My grateful acknowledgments for much kind assistance are due to Mr. W. F. Ferrier, once of this Survey, as lithologist, to whom was entrusted the determination and description of many of the microscopic sections, especially of some of the more critical ones; to Dr. F. D. Adams, of McGill University, Montreal, for aid and advice on some points connected with the petrography of the district; to Dr. H. M. Ami and Mr. L. M. Lambe, of this Survey, for their examination of the collections made from the several Palæozoic outliers and the preparation of detailed lists of the fossils.

Acknowledgments are also due to Mr. Colin Rankin and Mr. H. K. Beeston, of the Hudson's Bay Company, who did everything in their power to forward the objects of the exploration; to Messrs. Frank Norris, of Baie des Pères, John Turner, of Timagami lake, and Stephen Lafricain, of Bay lake, officers-in-charge at these several places or posts belonging to the same company; to Mr. M. H. McLeod, C.E., engineer-in-charge of the construction of the Timiskaming branch of the Canadian Pacific railway, and also to Messrs. J. C. Bailey, C.E., of Toronto, and H. K. Wickstead, C.E., of Cobourg, engineers-in-charge of the location of the projected Nipissing and James Bay railway, for information in regard to elevations at various points situated along or in the vicinity of the lines represented; to Mr. John Mann, of Baie des Pères; to Messrs. C. C. Farr and P. A. Cobbold, of Haileybury; to Messrs. J. B. and R. A. Klock, of Klock's Mills; to the Imperial Lumber Co., of Warren, Ont.; to Capt. Percy, late of the steamer *Meteor,* and Capt. J. O. Blondin, of the steamer *Clyde,* on Lake Timiskaming, and many others.

I have the honour to be, Sir,
Your obedient servant,
ALFRED ERNEST BARLOW.

Ottawa, January, 1907.

206807

NOTE.—*The bearings throughout this report are given with reference to the true meridian.*

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REPORT

(SECOND EDITION)

ON THE

GEOLOGY AND NATURAL RESOURCES

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NIPISSING AND TIMISKAMING MAP-SHEETS

COMPRISING PORTIONS OF THE

District of Nipissing, Ontario, and of the County of Pontiac, Quebec

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INTRODUCTORY.

The following report treats of that portion of the district of Nipissing, Ontario, and the county of Pontiac, Quebec, lying between latitudes 46° 13′ 21″ and 47° 36′ 47″ north, and extending from longitude 78° 49′ 54″ to longitude 80° 22′ 26″ west of Greenwich. This area is comprised in the two maps accompanying the report, known as the Nipissing and Timiskaming sheets, or Nos. 131 and 138 respectively, of the Ontario series of geological maps, on a scale of four miles to one inch. The district which each map represents measures seventy-two miles in length from east to west, and forty-eight miles from north to south, thus embracing an area of 3,456 square miles, or a combined area of 6,912 square miles. The Nipissing sheet includes nearly the whole of Lake Nipissing and considerable portions of Lakes Timagami, Timiskaming and Kipawa, the boundary between the two sheets cutting the three last-named lakes about latitude 46° 55′. The main line of the Canadian Pacific railway traverses the southern part of the Nipissing sheet, the eastern limit crossing the railway between Calvin and Eau Claire stations, while the western boundary is situated a short distance west of Warren station. The town of North Bay is the most populous and important place, and is one of the divisional points on the Canadian Pacific railway, as well as the present terminus of the Northern division of the Grand Trunk railway, although the actual intersection of the two lines is at Nipissing Junction, three miles southeast of North Bay. The Timiskaming and Northern Ontario railway, operated by a Commission appointed by the Government of Ontario, traverses this district from south to north. A portion of the border of the map, near the southeast corner, has been broken in order to show the position of the comparatively old and important town of Mattawa, at the confluence of the Ottawa and the Mattawa rivers, as well as the junction of the Timiskaming and Kipawa branches of the Canadian Pacific railway.

The Timiskaming sheet contains the northern parts of lakes Timagami, Timiskaming and Kipawa, and the southern portion of Lac des Quinze. The Ottawa river, from Mattawa to Lac des Quinze, flows through the region covered by the two maps, the deep-water channel of this stream forming the boundary between the provinces of Ontario and Quebec. There is thus an area of about 1,780 square miles situated within the province of Quebec, forming part of the county of Pontiac, while the remainder, 5,132 square miles, is included in the district of Nipissing, Ontario. Of the area situated in the province of Quebec only about 260 square miles have been surveyed into lots, included in the townships of Neudlac, Guigues, Baby, Duhamel, Laverlochère, Fabre and Gendreau, bordering on Lake Timiskaming; while in the province of Ontario an area of about 1,911 square miles has been laid off into townships and lots, the greater portion of which (1,685 square miles) is contained within the limits of the Nipissing sheet. The greater number of the townships on the Ontario side are of the more recent form adopted by the Crown Lands Department of that province, and measure six miles square, each township thus embracing an area of thirty-six square miles. Every township is divided into six concessions by east-and-west lines, run astronomically, which are designated by the Roman numerals, the order of numbering being from south to north, while the concessions themselves are subdivided into twelve lots by true north-and-south lines, which carry the ordinary Arabic figures. Each lot, therefore, measures one mile from north to south and half a mile from east to west, thus containing a superficies of 320 acres. Only every alternate lot-line is cut out through the bush, the intervening boundary being simply marked by a post on the concession line, these being known as 'blind lines.' A road allowance occurs every mile, coinciding with the township, concession, and side lines; while occasionally the 'blind lines' are utilized for this purpose. The lines are all supposed to be run astronomically east-and-west or north-and-south as the case may be, although in some instances no allowance has been made for the convergence of meridians, thus giving rise to considerable error and confusion. Bordering the Mattawa river and Lake Nipissing, as well as on the western shore of Lake Timiskaming, the townships are of a somewhat larger size, corresponding in this respect with those of southern Ontario, while to the south of the Mattawa river the townships belong to the older set, both in regard to size and the direction of their outlines and lines of subdivision.

On the Quebec side the townships seem to have no regular or stated size, and while the lines are astronomical their direction is determined by the general trend of the water-front. As a consequence, the lines of subdivision in the townships of Guigues, Duhamel, &c., are all run north-and-south or east-and-west respectively, as the upper portion of Lake Timiskaming has, in general, a north-and-south direction, while the township boundaries and side-lines of Gendreau and other townships situated in the southern part of Lake Timiskaming have a direction of N. 60° E. or at right angles to the general trend of the lake in this vicinity, which is thirty degrees east of south. The distance between concession-lines is slightly over a mile, but the lots themselves are much narrower than those on the Ontario side, each being designed to contain about 100 acres, although in many instances this area is much diminished or increased. The concessions are denoted by the Roman numerals, while the ordinary figures are applied to the lots. Occasionally, both in Ontario and Quebec, the letters of the alphabet have been used to designate the concessions.

The preliminary part of the work in this district was done in 1887-88, while acting under instructions from Dr. R. Bell, as his assistant; but only about two months of each season were devoted to this work, and by far the greater portion of this time was occupied in some of the many detailed surveys necessary in a region concerning which but little had hitherto been known. This topographical survey was, of course, accompanied by as many observations regarding the nature and distribution of the various rock formations encountered as was possible in a survey of the kind.

The more pressing nature of the work in connexion with the Sudbury mining district caused my removal from this field to assist Dr. Bell in tracing out the geological and topographical details necessary for the map and report concerning that region, so that work was not resumed on the Nipissing and Timiskaming sheets until 1892. The bulk of the work on these two maps was accomplished between 1892 and 1894, although about two months of the season of 1895 was required to complete it. It was found necessary to make a large number of topographical surveys, especially in the northern part of the district, and this portion of the work occupied by far the greater portion of our time and attention; but the detailed results thus obtained have added largely to our geographical knowledge of a region of which the physical features were but rudely represented, if at all, on the maps hitherto published.

The distances were measured with a Rochon micrometer telescope, while the direction was determined by prismatic compass. The distances thus obtained from point to point were further utilized as bases for a compass triangulation, by which the position of many of the smaller islands and some of the more conspicuous points on the mainland, otherwise inaccessible, were defined with sufficient accuracy. About the middle of July, 1887, agreeably with instructions received from Dr. Bell, then in charge of the work in the district of Nipissing, I proceeded from Lake Timiskaming by way of the Matabitchouan river and Rabbit lake to Timagami lake, in order to complete a detailed topographical and geological survey of that lake. This survey was commenced on July 23rd. The work was considerably retarded owing to the frequent presence of smoke caused by the unusually large number of bush fires, and on many days this smoke was so dense as to render all attempts at surveying quite useless. Another cause which militated very greatly against the rapid and successful prosecution of the work during this and succeeding seasons was the difficulty in procuring and retaining the services of suitable canoemen. In spite of these drawbacks, however, the survey of Timagami lake was finished by September 15th, when a similar survey was undertaken of the route by way of White-bear and Rabbit lakes and the Matabitchouan river to Lake Timiskaming. During the summer of 1888 these surveys were continued, but scarcely two months of the season were devoted to field operations in this region. During this time, however, considerable progress was made in the topographical measurements of many of the principal lakes, among the more important of which may be mentioned Cross lake, the northern part of Obabika lake, route from the north arm of Lake Timagami by way of Red-squirrel and Annima-Nipissing lakes to Bay lake on the Montreal river, as well as of many minor sheets of water to the north and northeast of Timagami lake.

In 1892 the survey and examination of the Nipissing district was resumed, with instructions from the Director to make whatever surveys were deemed necessary for maps and a report of an approximately final character. An epitomized statement of the general progress of the work has been given each year, in which mention is also made of the various topographical surveys accomplished each season, in the four Summary Reports of 1892 to 1895.* During 1892 and 1893 I was ably assisted by Mr. J. F. E. Johnston, upon whom devolved the greater part of the topographical work done during these two years. In 1888, and again in 1893 and 1894, I was accompanied by Mr. A. M. Campbell, of Perth. During the season of 1893 I had likewise the advantage of the assistance of Mr. E. M. Burwash, of Victoria University, Toronto.

For cartographical purposes, the various base, meridian and township lines run by the Crown Lands Departments of Ontario and Quebec have been utilized, and serve as excellent checks and corrections to the errors necessarily incident to a micrometer and compass survey. The geographical features of the area covered by the surveyed townships have, in the main, been adopted, supplemented, however, in many cases by additions and corrections of our own, which were sometimes found necessary. This information was chiefly available in the area of the Nipissing sheet, where over half the area has been divided into townships, and these in turn subdivided into concessions and lots. Besides these a number of surveys of a more general character have been made, the manuscripts and published plans of which have been found of much assistance in the general compilation, as well as in furnishing details in many cases not otherwise obtainable. Among the more important of these plans the following may be mentioned: Murray's survey of Lake Nipissing and the Sturgeon river, and Logan's survey of the Mattawa river, published in the folio atlas to accompany the Report of this Survey of 1853-56. Murray's survey of Lake Nipissing, however, did not show sufficient detail in the western portion of the lake, so that a re-survey was carried out early in 1892. Austen's map of the Timagami river, with accompanying traverses made for the purpose of ascertaining the most feasible route for the location of a transcontinental railway line, has also been used. Forrest's survey of the Montreal river was found excellent for all purposes for which it was required. Messrs. O'Dwyer and O'Hanley's survey of the Ottawa river and Lake Timiskaming, to delineate the boundary line between Ontario and Quebec, was found to be thoroughly reliable, while the Canadian Pacific Railway surveys enabled us to locate the exact position of the railway line.

Early Explorations and Previous Surveys.

The history of the exploration of the region in the vicinity of the Upper Ottawa and Mattawa rivers dates back almost to the first settlement of Canada by the French. The almost invariable presence of detached parties of the war-like and much dreaded Iroquois in the region immediately adjacent to the upper St. Lawrence usually forbade the utilization of this main artery as a route towards the west, so that in most instances the more peaceable, though more circuitous, passage by way of the Mattawa and the upper Ottawa rivers was the only practicable channel of communiction between the scattered French settlements on the Lower St. Lawrence and the populous villages of the Hurons and other friendly Indian tribes inhabiting the region in the vicinity of Georgian bay and Lake Simcoe. It is, therefore, not surprising to find that the various physical features presented in the regions in the vicinity of these streams were at a very early date among the best known, being especially familiar to the missionary and fur-trader, whose avocations forced them to make constantly recurring visits to the outposts already established in the distant west and northwest. The most prominent of these geographical features were appropriately designated, and most of the names then bestowed upon the numerous rapids, portages, &c., are still retained in common use throughout the district.

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* Summary Report, Geol. Surv. Can., 1892, Part A, pp. 34-35. 1893, Part A, pp. 30-33. 1894, Part A, pp. 55-57. 1895, Part A, pp. 61-63.

The sheltered nature of its water-stretches, its comparative freedom from molestation, as well as its directness as a route to the great lakes and beyond, formed powerful inducements in favour of the original selection of the Ottawa and Nipissing route, at a time when the birch-bark canoe was the chief, and often the only, method of communication. The advent of steamboat navigation on the St. Lawrence river and the great lakes, however, as well as the building of the St. Lawrence canals, has during the present century caused this route to fall into comparative disuse. The recently revived proposal to make use of these water-courses for purposes of modern navigation by the building of canals to overcome the obstructing rapids seems likely again to bring this district into prominence.

Soon after his arrival in this country, Samuel de Champlain, who was by nature more of an explorer and adventurer than a builder of colonies, determined on an examination of the headwaters of the Ottawa and beyond. He was all the more eager to undertake this investigation as a young man, Nicolas du Vignau, had just returned, in 1612, after a year's absence among the Ottawa Indians, with a most wonderful tale. He claimed, during his absence, to have discovered a passage by way of the Upper Ottawa to the shores of a northern sea to which he had penetrated and there beheld the wreck of an English ship. The apparent clearness and consistency of the story deceived Champlain, who fancied that he might thus find the much coveted road to China and Japan. Towards the end of May, 1613, Champlain, accompanied by this Du Vignau, ascended the Ottawa as far as Lake Coulonge, where he was reluctantly dissuaded by the resident natives from proceeding farther. They urged, as their main excuse for not seeming willing to guide him, the many insuperable difficulties to be encountered on the route, as well as the reputed fierceness and witchcraft of the Nipissing Indians, through whose country it was necessary to pass. Here also he learned that the whole story of Du Vignau's pretended discoveries was a fabrication, and that far from undertaking any such important journey as reported he had resided continuously and quietly at the village during the entire period of his absence from civilization. This information, which was subsequently corroborated by Du Vignau's own tardy confession, enraged and disheartened Champlain, who, convinced of the fruitlessness of any further effort at the time in this direction, returned to Montreal, and subsequently to France.

Early in 1615, however, Champlain returned to Canada, bringing with him four Recollets, one of whom, Father Joseph Le Caron, was destined for missionary work among the Huron Indians. Arriving at Montreal he found a large concourse of Indians already assembled, who had come hither from their homes in the vicinity of Lake Simcoe. These savages, always more eager for temporal than spiritual help, again pressed Champlain to aid them against their hereditary foe, the formidable Iroquois. Deeming it expedient at the time to comply with this oft-repeated request, Champlain hurriedly descended to Quebec to make the necessary preparations, leaving Le Caron and some of his compatriots with the assembled Indians to await his return. During Champlain's absence, however, the Indians decided to go back forthwith to their own home without him, and accompanied by Le Caron and his associates commenced the ascent of the Ottawa river. When Champlain returned to Montreal and found the place deserted he immediately hurried after them, pursuing the usual course up the Ottawa and Mattawa rivers, over the height-of-land to Lake Nipissing and thence down the French river to Lake Huron. Champlain was thus the first European, with the exception of the humble friar who had only just preceded him by a few days, to gaze on the waters of Lake Huron, which he christened 'Mer Douce.'

Champlain's map of New France, which was made in 1632, included all sketches and surveys from 1603 to 1629. Only the main routes of travel are represented, while the whole map exhibits, in a very rough manner, the salient physical features encountered during the progress of these journeys and explorations. Lake Nipissing is called 'Lac de Biserinis,' while a rude outline of the Ottawa river above its confluence with the Mattawa is given that must have been drawn from information supplied by the Indians.

The exploration of this district, as of others elsewhere throughout Canada, is inseparably bound up with the history of the fur trade, the successful prosecution and extension of which required the constant addition of new territory. We thus find that many of the first exploratory expeditions were often undertaken by adventurers at their own expense, with the promise of various marks of distinction from those in authority in case of the success of their undertakings, while fur-trading licenses were granted to enable these men to indemnify themselves for their pecuniary outlay.

The limits of this traffic were quickly extended both northward and westward, and we find by reference to Delisle's map (1703) that the French then had a post (Fort des Abitibis) north of the height-of-land on the river Abitibi. This post, according to the memorial of Begon,* was the most advanced station of the French toward Hudson bay. From this same memorial it also appears certain that the route northward by way of Lake Timiskaming and the Abitibi river (Monsony or Monsipy) was one of the best known, although the French traders avoided the immediate vicinity of Hudson bay in order not to expose themselves to the insults of the Indians who were friendly to and traded with the English posts already established in that vicinity. It does not seem unreasonable to suppose, therefore, that some of the expeditions despatched by the Governors of Canada toward the close of the seventeenth century, to take possession of Hudson bay, adopted this well known route by way of the Upper Ottawa and Abitibi rivers. All the earlier maps indicate many of the streams flowing northward from the height-of-land into James bay with tolerable accuracy, thus showing that the early voyageurs were well acquainted with this portion of the country.

Fort Timiskaming must have been one of the first posts established by the Northwest Company, if not acquired after its abandonment by the French, for Mr. Roderic Mackenzie, a clerk in this Company, who wrote 'A General History of the Fur Trade,'† which forms the opening chapter of Sir Alexander Mackenzie's Travels in North America, says: 'Lake Timiskaming, where there has always been a trading post,' while one of the buildings which had been used as a storehouse and which was removed only a few years ago, bore dates on the large cedar beams which pointed to its erection some time near the close of last century.

Fort Timiskaming afterwards became the headquarters of the Hudson's Bay Company in this district, containing the residence of the Chief Factor and all the necessary adjuncts in the shape of buildings, &c., which usually go to make up a well equipped establishment. forming one of the most important centres of the fur trade, and containing, besides, a library embracing many volumes on science, travels and general literature. In 1888, however, this post, so long established, was abandoned, and a small store was erected at 'The Point' near the village of Baie des Pères, which was found more convenient for purposes of general trading; while the opening up of the Canadian Pacific railway had previously caused the removal of the headquarters to Mattawa.

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*Mémoire de Begon, Oct. 20 1725, qui explique les anciennes limites du poste de Témiscamingue.

†Voyages from Montreal through the Continent of North America to the Frozen and Pacific Oceans in the years 1789 and 1793. London, 1801. p. xxxiv.

Timagami post, now situated on the west side of Bear island on Lake Timagami, was moved to its present site in 1875, on account of the opening of an opposition fur-trading establishment owned by Alexander Dukis, who soon left his stronger rival in undisputed possession of the place. Before its removal thence this post was located on the shores of a small cove on the south side of Timagami island, and ruins of the buildings are still visible at this place. Fort Wrath, of which the tumbled-down buildings may even now be noticed on the east shore of Lake Timiskaming about a mile above Piché point, was built to overcome the rival post operated by Mr. Edward Piché, who still resides at his farm on the point which bears his name. This place was kept open for a few years only, when the necessity for its presence ceased. The somewhat important post near the mouth of the Sturgeon river continued actively engaged in trade with the Indians until the opening of the railway, when it gradually fell into disuse and was finally abandoned altogether about the year 1890. Hunters Lodge, originally a trading establishment, situated on Hunters narrows in Kipawa lake, was abandoned about the same time. At several points on the Ottawa river and the lower portions of Lake Timiskaming, temporary posts were erected from time to time, but these were of no permanent importance, and when the reasons which brought them into existence disappeared, they were given up and forgotten. Buildings originally erected in 1887, and designed for storage purposes on Bay lake, an expansion of the Montreal river, have since been raised to the dignity of a post with an officer in charge. At present, in the area of the accompanying map-sheets, there are only three establishments, Timagami, Bay lake and Long point (on 'Quinze lake'), which receive any great quantity of furs, although a considerable number of skins come in casually to the posts at Mattawa and Baie des Pères during each year. Of these Timagami is the most important, but the gradual opening up of considerable areas in this district to settlement, and the diminution in point of number both of the fur-bearing animals and the Indians who are chiefly engaged in their capture, is already having a marked effect, showing a gradual, or in some cases a rapid, decrease in the number of skins annually brought to market.

The opening chapters of Mackenzie's narrative, previously mentioned, give a brief description of the route generally pursued by the fur-trading canoes in gaining access to the various forts and trading posts of the interior. The rapids and portages of the Mattawa are enumerated, the names in most cases being the same as those in use at the present time, although the river itself is here called Petite rivière. Nepisingui (Nipissing) lake is also mentioned, and a short account given of the Rivière des François.* The first geological account of the region in question was that of Dr. J. J. Bigsby, who had come to Canada as medical officer to a regiment. About the year 1820 he received an appointment from the Colonial Government to make a general report on the geology of Upper Canada, the absurdly small sum of twenty-six pounds, as he informs us, being granted as pecuniary aid to carry out this extensive undertaking. Dr. Bigsby first made an examination of the Ottawa, Mattawa and French rivers, together with Lake Nipissing, having been granted a free passage to Sault Ste. Marie in one of the Northwest Company's canoes. He gives a good account of the Ottawa river itself and of the country adjoining this stream, and mentions that the Mattawa river, which was the western branch of the Ottawa, often called the Little Ottawa, was known as the Tessouac river by the Indians. The occurrence of crystalline limestones at the Talon chute is noticed, among other interesting facts. The position of 'La Ronde,' a Northwest Company's post, is noted as being situated at the mouth of the Vase river, as well as its subsequent removal to one of the islands in Lake Nipissing.†

During the progress of the magnetic survey of British North America, executed between 1842-1844 by Sir J. H. Lefroy, various observations were taken in this region to ascertain the magnetic variation, while latitudes were obtained at the following places: Hudson's Bay Company's post, Mattawa; First portage on Little (Mattawa) river, Lake Temisique (Lower Trout lake); Lake de Talon or Lake Walrond; Trout lake, formerly called Lake de Grande Vase; Height-of-land portage, towards Lake Nipissing; and Cross point on the south shore of Lake Nipissing, where a cross had been erected to commemorate some fatal accident.*

For many years the region in the vicinity of the Upper Ottawa river was comparatively unknown, except to the occasional traveller and missionary, and to those engaged in the fur trade, whose business necessitated constant journeying to and fro along the main canoe-routes. In time, however, the almost inexhaustible supply of valuable timber known to exist in this district attracted the attention of the enterprising lumberman, whose operations were so quickly extended northwestward that by the year 1845 we find that lumber camps were in full operation in the vicinity of the Opimika narrows (the 'Galère'), while some two or three years previously red pine timber had been cut on Lake Timiskaming several miles above the Narrows at the Hudson's Bay Company's post. These lumbering out-

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*See pp. xxxiv. and xxxv. Mackenzie's Voyages.
†Shoe and Canoe, vol. I. London, 1850. pp. 105 to 171.
*See Lefroy's Magnetic Survey of the Dominion of Canada. London, 1883.

posts, however, were for the purpose of cutting red pine alone, the value of which at this time caused it to be sought for at greater distances than the white pine; for previous to this no white pine had been cut higher than Bennett brook, on the Ottawa river.

The first really accurate delineation of the topographical features within the area comprised by the two accompanying map-sheets was made by Sir William E. Logan, the founder and first Director of the Geological Survey of Canada, in the year 1845.†

A geological section across the western part of Canada, from Lake Huron to Lake Erie, having previously been made by Mr. Alexander Murray, in 1843, in addition to an examination into the stratigraphical relation of the rocks comprising the extreme eastern portion of Canada, by Sir William Logan himself, it was considered expedient that a third section should be undertaken across and embracing some part of the northern district. The Ottawa river was chosen for various reasons, the chief of which was perhaps its accessibility and the greater immediate utility to the country at large which such a survey promised. Starting from Montreal he made an examination of the various rock formations exposed on the shore of the Ottawa, taking occasional short excursions inland wherever deemed necessary. This geological investigation was continued as far as the mouth of Bennett brook, about five miles above the 'des Joachim' rapids. As this was the highest point yet reached in the topographical delineation of the course of the Ottawa it was decided to make this the starting point of the contemplated survey of the upper portion of this stream. The distances were determined by the Rochon micrometer telescope, while the bearings and angles of intersection were obtained by means of a theodolite. The differences in level of the river at all the rapids were ascertained by careful levelling with a proper instrument and staff, the fall in the intervening stretches being estimated from a knowledge of the strength of the current. This survey was continued up the Ottawa as far as the first chute on the Rivière des Quinze, a short distance above the head of Lake Timiskaming. During the same season, and as a necessary adjunct, a similar survey was undertaken of the Mattawa river, from its junction with the Ottawa to its headwaters in Trout lake, including also the portage-route by way of the Rivière de la Vase to Lake Nipissing, as well as a small portion of the shore-line of this lake in the vicinity of the mouth of this inlet. Observations for latitude were obtained at the starting point, the mouth of the Mattawa, the mouth of the Vase on Lake Nipissing, as well as at the mouth of the Kipawa on Lake Timiskaming. In fact every precaution was taken to make this survey as accurate as was possible with the instruments and time at his disposal. The various topographical details, delineated in a map subsequently compiled by Sir William Logan himself on a scale of one mile to an inch, bearing valuable notes regarding the various rock formations encountered, is at present on file at this office, and although not issued as a separate publication, the information has been made use of in every subsequent map covering the district.

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†Report of Progress, Geol. Surv. Can., 1845-46.

A portion of the Ottawa river in the neighbourhood of the Mattawa, as well as the whole of this latter stream, were, however, incorporated in the atlas to accompany the report by Mr. Alexander Murray (1853-56). During the summer and autumn of 1854 Mr. Alexander Murray, of this Survey, was engaged in making exploratory surveys to the east of Lake Huron and Georgian bay. These included a survey of the southern shore of Lake Nipissing, from the point where the French River measurement ceased in 1847, to the mouth of the Vase, where connexion was made with Sir William Logan's survey of 1845, and thence of the north shore of this sheet of water to its 'northwest angle.'* In 1855 Mr. Murray continued this survey, commencing at the outlet of Lake Nipissing into the French river, along the western coast, making connexion with the work of the previous year.** In 1856 this survey was again extended, this time a start being made from the Hudson's Bay Company's post on Sturgeon river near Lake Nipissing.

Ascending the Sturgeon river for about fifty-two miles to the mouth of the Maskinongé, the measurements were carried up this important branch through Murray, Washkigamog, Maskinongé-wagaming and Mattagamashing lakes to Wanapitei lake, and down the Wanapitei river to Lake Huron.†

In 1855 Duncan Sinclair made a survey of Kipawa lake, with a view of defining and locating certain timber limits. This survey, although excellent for the purpose for which it was undertaken, nevertheless lacked certain details essential for a correct elucidation of the geological features, thus necessitating a re-survey, which was accomplished by Mr. J. F. E. Johnston of this Department.

Acting under instructions from the Commissioner of Public Works, Mr. Walter Shanley, C.E.,† in 1856-57 made a detailed examination of the route contemplated for a canal to connect the waters of the St.

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*Report of Progress, Geol. Surv. Can., 1853-56, p. 101 et seq.

**Report of Progress, Geol. Surv. Can., 1853-56 pp. 123 and 135 et seq.

†Report of Progress, Geol. Surv. Can., 1853-56, pp. 145 et seq.

‡Report of Walter Shanly, Esq., On the Ottawa Survey,—Toronto. March 22nd, 1858. Also Report on the Ottawa and French River Navigation Project,—Published by order of the Montreal Board of Trade, 1863.

Lawrence with those of the Great lakes by way of the Ottawa, Mattawa and French rivers, and Lake Nipissing.

In 1858-59 another examination of the same route was made by Mr. T. C. Clarke, C.E.,[§] also in accordance with instructions received from the Commissioner of Public Works.

In 1867 Mr. A. G. Forrest, acting under instructions from the Crown Lands Department of Ontario, made a survey with transit and chain of the Montreal river, starting from its intersection with a due west astronomical line, supposed to be run on the parallel of latitude of 47° 56′, between Michipicoten harbour on Lake Superior and the head-waters of the Montreal river. This astronomical line was started about the same time from its eastern and western extremities. Mr. Duncan Sinclair, who was entrusted with the eastern portion of the line, succeeded in running a distance of 105 miles from the Montreal river, while Messrs. A. P. Slater and R. Gilmour ran eighty-four miles eastward from Michipicoten harbour. Mr. Forrest, from the intersection with Sinclair's line, made an instrumental traverse of the Montreal river to its mouth on Lake Timiskaming, a distance of one hundred and one and a quarter miles, at the same time taking notes on the timber and other natural resources of the country extending for three miles on either side of the stream. These surveys, commenced in 1866, were completed in 1867. Their primary object seems to have been to determine the feasibility of the construction of either a wagon road or railway to the Red River country through the district in question.[*]

About the same time, (June 13th to August 16th, 1867), Mr. Lindsay Russell made a micrometer traverse of Lac des Quinze and the Upper Ottawa, connecting with H. C. Symmes' survey of Grand lake. Mr. Russell during the same season made a similar survey of the route to Lake Abitibi, as well as a traverse of this large sheet of lake, then for the first time correctly measured.[†]

In 1871 Mr. Alexander McKenzie, acting under instructions from Mr. James H. Rowan, who had charge of the Canadian Pacific Railway surveys from the Mattawa to the Red river, made a track-survey northward by the Ottawa and Abitibi rivers to James bay, returning by way of the Moose and Michipicoten rivers to Lake Superior.[‡]

In 1871-72 Messrs. Lloyd, O'Hanly and Austen, also under Mr.

[§] Return of Recent Survey and Report of the Engineer on the Ottawa Ship Canal, Quebec, 1860, by Thos. C. Clarke, C.E.

[*] See remarks on Upper Canada surveys, 1867 pp. 56-62.

[†] See Report Commissioner of Crown Lands, Quebec, 1868, p. 17, also descriptions of the Surveyed Townships and Territories of the province of Quebec, 1889, pp. 416-424.

[‡] See Progress Report on Surveys Canadian Pacific railway, 1872, p. 74. Also Report on Surveys Canadian Pacific railway, 1877, pp. 5-47 and 48.

Rowan's instructions, made exploratory surveys from Mattawa by way of the Ottawa and Montreal rivers to a point about half-way between this latter stream and one of the branches of Moose river.[§]

In 1872 Mr. Walter McOuat of this Survey was engaged in a geological examination of that portion of the country to the north and east of Lake Timiskaming. The work performed by Mr. McOuat in the Timiskaming region embraced a most painstaking geological examination of Rivière des Quinze, Lac des Quinze and the route thence northward to Lake Abitibi, including a micrometer survey of the shores and islands of that lake. He also made a micrometer traverse of the Blanche river as far as Round lake, accompanied by an examination of the rocks in the immediate vicinity of this stream.[*] The plans to accompany his report have never been published, but the information contained has been utilized in subsequent general geological maps embracing this area.

In 1872-74 Messrs. O'Hanly and O'Dwyer, joint commissioners for Ontario and Quebec, made an instrumental traverse of the Ottawa from Mattawa to the head of Lake Timiskaming, and surveyed a line running northward from a point on the 'Chenail du Diable,' near the mouth of the Rivière des Quinze as far as the height-of-land.[†]

During the year 1876, in connexion with the location of the Canadian Pacific railway, Mr. Marcus Smith, then acting engineer-in-chief, made an examination of the eastern portion of Lake Nipissing, as well as of the 'Beuve' (Veuve) river as far as the forks, about twenty-five miles from the mouth.[‡]

In 1879 Mr. W. A. Austen, for the Canadian Pacific railway, ran a trial location survey from a point situated a short distance (404 feet) east of the deep-water landing at Southeast bay (or East bay) of Lake Nipissing, in a northeasterly direction for sixty-three miles up the valley of the Sturgeon river.[||] As a part of the same survey Mr. Austen made a micrometer survey of the Timagami river, the southern portions of Cross and Timagami lakes, as well as the route from thence to Maskinongé-wagaming lake, by way of Obabika and Wawiagama lakes.

[§] See Progress Report on Canadian Pacific Exploratory Surveys, 1872. These surveys comprised Divisions B, C and D, respectively, mentioned in these reports. The surveys were begun on June 10th, 1871, and the last of them was completed by July, 1872. See also Report on Surveys, Canadian Pacific railway, 1877, pp. 5 and 47.

[*] Report of Progress, Geol. Surv. Can., 1872-1873 pp. 112 et seq.

[†] The manuscript plan of a scale of 40 chains to one inch bears the date, Dec. 27th, 1875, while the joint report filed with the Crown Lands Department, is dated Ottawa, Dec. 7th, 1874.

[‡] Report Canadian Pacific railway, 1877, pp. 359-360.

[||] Appendix 18, "Report Canadian Pacific railway, 1880, pp. 290-296." A plan on 4000 feet to an inch, detailing these explorations, as also two profiles of the Sturgeon river, are on file at the Department of Railways and Canals, Ottawa, and have been of much assistance in the compilation of the accompanying maps.

During the summer of 1884, commencing in June, Mr. T. Guerin, engineer of the Public Works Department, Ottawa, undertook an examination of the Ottawa river and Lake Timiskaming, with a view to ascertaining the feasibility, at a reasonable cost, of the various schemes urged on the government from time to time, looking to an increased facility in the navigation of these waters.||

In the summer of 1884 Dr. Selwyn, during the progress of an examination of the numerous rock-cuts exposed along the line of the Canadian Pacific railway, paid a visit to the Manitou islands in Lake Nipissing, and the list of the fossils then collected from the Cambro-Silurian outliers comprising seventeen species, together with a few notes regarding their occurrence, was published by Dr. H. M. Ami.*

The Rev. J. M. Goodwillie, who was stationed at North Bay for some years, has made an extensive collection of the fossil remains from these islands, and these have now been examined and their identification has greatly added to the list appended to this report.

Mr. Ulrich determined a small collection of fossils for Professor N. H. Winchell, which were collected by Mr. T. D. Ledyard, of Toronto.† In 1889, Prof. N. H. Winchell paid a visit to North Bay, and gives a record of his observations made in that vicinity.‡

In 1889 Mr. G. K. Gilbert made an examination of the vicinity of North Bay and the country eastwards towards Mattawa, with a view to obtaining any evidence regarding the former existence of an outlet for the Great lakes immediately following the retirement of the ice-sheet. The possibility, and even the probability, of the existence of such an outlet had been looked upon for some time with favour by some geologists, although facts in support of these views were not forthcoming previous to the communication made by Mr. G. K. Gilbert to the meeting of the American Association for the Advancement of Science, held in Toronto in August, 1889. The general substance of the remarks then made was published under the title of 'The History of the Niagara river.'§

In September, 1892, Prof. G. F. Wright visited the neighbourhood

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||Ann. Rep. Minister of Public Works, 1884-85, pp. 103-124.

*Can. Rec. Science, April, 1892, pp. 108 et seq.

†American Geologist, vol. XVIII., No. 3, September, 1896, p. 178.

‡Eighteenth Annual Report, Geol. and Nat. Hist. Survey, Minnesota, 1889, p. 501.

§Sixth Annual Report of the Commissioners of the State Reservation at Niagara for 1889, pp. 61-84, and reprinted in the Smithsonian Report for 1890, pp. 231-257.

of North Bay and Mattawa, making certain observations seemingly confirmatory of the former existence in the Mattawa valley of this outlet, embodying the results of his observations in a paper entitled, 'The Supposed Post-glacial Outlet of the Great lakes through Lake Nipissing and the Mattawa river.'[‖]

In the autumn of 1893 Mr. F. B. Taylor made some observations in regard to the occurrence of beaches in the vicinity of North Bay, and their relations to this supposed old outlet of the Great lakes. The results then obtained were communicated to the Geological Society of America, and published in the bulletin of that society.[*] In 1895 another visit was paid to the Nipissing district with the similar object of gaining additional information in regard to the recent changes of level.[†]

In 1896 a third visit was paid to the region in the neighbourhood of the Mattawa and Ottawa rivers, and the results then obtained were communicated to the Geological Society of America.

In 1890 William Ogilvie, acting under instructions from the Department of the Interior, Ottawa, fixed the latitude and longitude of Mattawa, the latter by telegraph from Ottawa.

In 1892 Messrs. H. K. Wicksteed and Patterson, under the direction of Mr. J. C. Bailey, C.E., of Toronto, made the location survey of the Nipissing and James Bay railway from North Bay to the Northeast Arm of Lake Timagami. Mr. Patterson had charge of the location of the southern portion of the line from North Bay to Marten lake, and Mr. Wicksteed of the northern part.

The building of the Timiskaming branch of the Canadian Pacific railway, and the surveys and levels made in connexion therewith, have been used in the present map and report, the information being kindly supplied by Mr. M. H. McLeod, the engineer-in-charge.

General Physical Features.

The general character of the country may perhaps be best described as that of an uneven or undulating rocky plateau, with a gentle slope towards the east and southeast. Although in detail the surface of this plateau is far from uniform, consisting of a succession of more or less parallel rocky ridges, with intervening valleys occupied by swamps or lakes, still the district as a whole has a general elevation varying from 900 to 1,200 feet above the sea. There are no very prominent hills, the highest seldom attaining a greater altitude than

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[‖] Bull. Geol. Soc. Am., vol. IV., 1893, with discussion by Dr. Robert Bell, pp. 423-426.

[*] Bull. Geol. Soc. Am., vol. V., pp. 620-626 with two maps, also American Geologist, vol. XIV., Nov., 1894, pp. 282-285.

[†] *Ibid*, vol. XVIII., August, 1896, pp. 108-120.

300 feet above the surrounding region, while throughout most of the district hills of 50 to 100 feet in height are rather conspicuous topographical features. The highest land in the whole area is situated near the northwest corner of the Timiskaming sheet, immediately to the west of Lady Evelyn (Mus-ka-na-ning) lake, where a range of hills of which Maple mountain is the highest peak rises to the height of a little over 2,000 feet above the sea, according to Dr. Bell.

The influence exerted by the underlying rock on the general contour of the surface is perhaps nowhere better exemplified than in the region embraced in this report. In the southern and southeastern portions, where the prevailing rocks are the various gneisses and granites included as Laurentian, there are no hills of any great height, the general surface presenting, as usual, a rather monotonous succession of low rounded hills, with correspondingly shallow rocky valleys. In the northern and western portions, however, those areas in which the quartzites are present, as well as those in which the plutonic rocks, chiefly granite and diabase, are prevalent, rise into rather important elevations; while those regions which are underlain by the slaty member of the Huronian are on the other hand low and flat. A remarkable resemblance exists between the contour of the surface, occasioned by the presence of the diabasic rocks, and that produced by the heavy-bedded and massive quartzite that forms the highest member of the Huronian exposed in this district, both rising into comparatively high rounded or broken ridges, and rendering the stretches of country where such rocks prevail exceedingly rough and hilly. This is especially the case with the region to the north and northwest of Wakemika and Lady Evelyn lakes, and also between Friday and Whitebear lakes and the Montreal river; although the whole of the area coloured on the map as underlain by those rocks partakes essentially of this rugged character. This rough and broken contour is in marked contrast to the flat surface characteristic of the region in which the slates obtain.

The contrast is probably nowhere better shown than in the northeastern part of Lady Evelyn lake, where the quartzite which crosses the lake at the Obisaga narrows forms high and perpendicular cliffs for a short distance, while to the east, as far as the Waswaning narrows, the shore on both sides is low and swampy, with only a very occasional exposure of the flat-lying slaty rocks. At the elbow to the east of the Waswaning narrows a high ridge of diabase crosses the lake, forming rugged hills which constitute the western side of that portion of the lake known as the Mattawapika. Thus within a few miles, on the same lake, are exhibited examples of all three types of surface produced by the underlying quartzite, slate and diabase.

The large area coloured as granite, to the northeast of Lake Timagami, may perhaps be best described as a region of flooded *roches mountonnées,* for the hills are all low and rounded, while the intervening hollows are occupied by exceedingly intricate and shallow, swampy lakes or marshes. The valleys of the smaller rivers are usually narrow, and many of the streams are nothing but a succession of small lakes united by rapid rocky or bouldery discharging channels.

Probably one of the most interesting of the physical features presented by the district is the valley occupied by Lake Timiskaming and the Ottawa river. The greater portion of this valley is a very steep, rocky gorge, fringed on either side by lofty hills or perpendicular cliffs which rise abruptly to a height of from 400 to 600 feet above the surface of the water, while the average of a large number of soundings indicate that the lake has a mean depth of over 400 feet. The depression, therefore, occupied by these waters, would be about 1,000 feet below the level of the surrounding country, and as the bottom of the lake, wherever examined, consisted in the deeper portions of a very fine grey unctuous clay or silt, this depth may have been much greater before the accumulation of this material. From Mattawa to the mouth of the Montreal river these abrupt and rocky shore-lines prevail, but above the mouth of this stream the lake undergoes considerable expansion and the shores exhibit a more gradual slope towards the surface of the water. The traveller ascending the Ottawa river is thus usually impressed with the mountainous character of the district, but an ascent of the hills on either side at once shows that the adjoining country is comparatively level, and that what appeared as ranges of hills are in reality the enclosing walls of this great valley.

The Mattawa and Montreal rivers, and in a lesser degree the Sturgeon and Timagami rivers, occupy rather deep and important depressions in this rocky plateau.

The district is traversed with rivers which are as important and well known as the lakes which they serve alternately as inlet and outlet. The Ottawa is, of course, the largest, but only a portion of this, from Mattawa to Lac des Quinze, is included within the area of the accompanying map-sheets. The Sturgeon likewise finds its source beyond the confines of this region, as also does the Montreal river, although by far the greatest portion of both streams is represented on the present maps. The Sturgeon is the larger of these two rivers, draining about 3,000 square miles, while the Montreal drains an area of about 2,500 square miles. The Matabitchouan, Mattawa, Kipawa, Timagami, Otter-tail and Otter rivers are also worthy of mention, although much smaller than the rivers first named. The

Blanche river is a stream of considerable size, but only a small part of the lower portion is included in the Timiskaming sheet.

In common with other regions characterized by the presence of Archæan rocks this district is remarkable for the number of lakes, both large and small, which are scattered over its surface. These lakes are in themselves noteworthy, not only for their many intricacies, but also because of the great number of islands which dot their surfaces. At first sight these lakes are seemingly governed by no law in regard to their distribution, but a somewhat closer examination reveals the dependence of geographical outline on the geological structure. In order to bring out more fully the intimate relation subsisting between the topographical outline and the nature and attitude of the enclosing strata, a careful compilation and correlation of the various strikes or direction of the foliation of the gneisses has been made, exhibiting with as close an approximation to the truth as is possible the various curves and folds assumed by these rocks.

The following nine lakes, with their areas and elevation above mean sea-level, may be particularly noted:—

	Area. Square Miles.	Height above sea.
Lake Nipissing	345	640·5–647·8
" Timiskaming	125	577·8–591·8
" Kipawa	120	873·7–883
" Timagami	100	964
Lac des Quinze	40	845
Lady Evelyn lake	18	930
Obabika lake	11	932
Obashing lake	11	822
Rabbit lake	8	938

Lake Timagami, during the earlier portion of the summer, drains both northward, by way of Nonwakaming and Lady Evelyn lakes into the Montreal river, and southward by way of Cross lake and Timagami river into the Sturgeon, the water thus ultimately finding its way into Georgian bay and Lake Huron. The southern outlet, however, is the larger and deeper stream, while the northern one is usually dry towards the end of July each summer, and is thus only utilized in time of high water. Rabbit lake finds its main outlet into the Matabitchouan river from the northeast corner of the lake, but a bay extending to the southeast is connected at extreme high water with Ross and Burwash lakes at the head of Macdonald creek, which in turn empties into the Matabitchouan river at the Fourth Bass lake. Annima-Nipissing lake, a large and important sheet of water situated between Lake Timagami and the Montreal river, which has usually, as the name implies, been regarded as the ultimate source of the Nipissing water, is 1,070 feet above the sea, while Breeches lake, which is in reality at the summit, is 1,085 feet above the sea. The highest lake in the whole region is Wilson lake, at the head of one of the branches of the Matabitchouan river, and this is 1,173 feet above the sea, while the height-of-land between this lake and the Montreal river is a little over 1,200 feet above the sea.

Denudation.

In many of the descriptions which have from time to time appeared concerning this, in common with other Archæan regions, undue prominence has been given to the erosive effect produced during the glacial epoch. The prodigious number of lakes both great and small which are so emiently characteristic of districts underlain by Archæan rocks have in general been referred to as original rock-basins which owed their existence to the excavating power of an immense glacier, while the mammillated hills and complementary valleys everywhere prevalent, as well as the constant occurrence of parallel grooves and scratches, have been adduced as additional evidence of the adequacy of the glacier to produce all the inequalities of the existing surface. The detailed examination of the region, however, amply demonstrates that the sculpturing to which the surface owes its present configuration was practically completed long before the advent of the glacial epoch, and that the main valleys, especially those of the Ottawa and Mattawa rivers, were in existence long prior to the deposition of the Palæozoic sediments.

In the first place the more important lakes and rivers occupy such deep and extended depressions that they seem inexplicable on any theory of glacial action or ordinary erosion by water. The bottom of Lake Timiskaming is on an average about a thousand feet below the level of the surrounding country, and in no place did the sounding lead reveal the original rocky bottom which has been more or less deeply covered by silts and by accumulations of drift material. Portions of the Mattawa and Montreal rivers are fully six hundred feet below the level of the rocky plateau through which they flow, and in many places exhibit steep, often perpendicular banks, composed of the hardest and most massive crystalline rocks.

Secondly, the trend of many of these valleys does not coincide with the general direction of the ice-flow, as revealed by the striæ and grooves which mark many of the exposed rock-surfaces of the plateau. These striæ in general vary from S. 10° W. to S. 30° W., while S. 20° W. may be assumed as a fair average of the direction of the ice-flow throughout this region. The deepest valley, that occupied by Lake Timiskaming and the Ottawa river from the mouth of Wabi creek to its confluence with the Mattawa river, has a direction of S.

30° E. while the valley of the Mattawa runs about east-and-west, thus forming considerable angles with the general striation, while the Montreal and Sturgeon rivers are intersected almost at right angles by these grooves and scratches. On the shores of Lake Timiskaming, and also on the Montreal river, many of the striæ exhibited have a direction corresponding with these valleys. These may either represent a differential movement in the mass of the ice itself, whereby the lower portion was forced by reason of its plasticity to conform to the inequalities of the existing surface while the upper portion continued on its general southwesterly course; or, as seems more probable, these grooves may have belonged to a local glacier occupying these valleys towards the close of the glacial period. On the upper or wider portion of Lake Timiskaming striæ belonging to the general glaciation may be noticed on the same rock-surface as other markings which belong to this local glacier, but the more abundant and strongly marked grooves throughout the lower portion of the valley are seen conforming to its various changes of direction.

Again, many of these valleys do not correspond with the strike of the rock in their immediate vicinity. The Ottawa valley is the best illustration of this fact, for the foliation of the gneissic rocks which compose most of its shores intersect this gorge almost at right angles. The depressions occupied by the Sturgeon and Montreal rivers also form considerable angles with the strike of the rocks in the immediate neighbourhood. Very often the streams occupy singularly straight and deep chasms in very hard rocks of different composition, valleys which it seems impossible that the ordinary erosive action of ice or water could ever have opened up, and which preserve their uniform direction with very little deviation in their course, even when the river has left a softer rock to enter an area where the hardest varieties prevail.

The Montreal river, from 'The Notch,' near its mouth, to the bend above the portage to Mud lake, a distance of twenty-one miles, flows through a rocky gorge, the course of which is in general N. 40° W. At this point the course of the valley changes abruptly to S. 45° W., which is maintained until Bay lake is reached, a distance of four miles. From this point upward a valley extends as far as the Great Bend, beyond the confines of the present map, which is almost if not quite parallel to that occupied by the river below Mud Lake portage. Of course the river presents many minor deviations in its downward course, but the remarkable uniformity in direction of the valley through which the stream meanders is maintained through successive alternations of slate, quartzite, greywacké and diabase, the character and composition of the surrounding rocks having apparently little or no effect in determining the course of this depression.

The existence, likewise, of Palæozoic outliers occupying portions of these valleys, seems ample proof of their existence as such from a very early time. The occurrence of an outlier of limestones, shales and conglomerates belonging to the Niagara was noticed by Sir William Logan on Lake Timiskaming in 1844. This outlier appears as a shallow syncline resting unconformably on the slates and quartzites of the Huronian. The conglomerate, grit and arenaceous limestones representing the basal portion of the section may be seen forming a narrow fringe from Piché point to Chief island, on the east side of Lake Timiskaming, while a small patch of similar rocks crops out on the west side from Haileybury northward towards Wabi bay. The limestones are present on the islands to the north of Bryson island, and on the peninsula between Sutton and Wabi bays extending beyond the limits of the present map. The boulder-conglomerate that occupies the eastern shore to the south of Chief island is composed of large angular or subangular blocks derived from the Huronian quartzite which forms rather abrupt hills immediately behind this exposure. These detached fragments doubtless represent what was originally a talus, formed at the foot of this steep slope, and when the submergence took place the intervening spaces became filled with detritus composed of the same materials, in a finer state of division, together with a small proportion of calcareous matter. This conglomerate and grit rest upon a surface which had clearly assumed a hummocky character before the deposition of these sediments, while the action of the glacier flowing down Lake Timiskaming long afterwards striated and polished the whole, leaving a surface with a net-like structure, through the meshes of which protrude rounded or ovoid sections of these rocky hillocks. Limestones and sandstones of Black River age are seen resting on the mammillated surfaces of Laurentian gneiss on the Ottawa, six miles below Mattawa, and also about five miles above Deux Rivières, as well as on the Manitou islands, Lake Nipissing, while sandstones which are probably of Chazy age, but which have yielded no fossils, were noticed on Iron island in the same lake.

The occurrence of such outliers at various points throughout these valleys shows that they existed in very early Palæozoic times, and indicate the transgression of the sea thus far inland at intervals during this, the Palæozoic, the submergence having been greatest during the Niagara, when the sea reached the northern end of Lake Timiskaming and may possibly have been connected by narrow arms and straits with that extending southward from Hudson bay.

The rounded or *moutonnée* surfaces of all these rocky elevations, though no doubt accentuated by later glacial action, have in the first place been due to the unequal progress of rock decay. The work of Lawson, Low, Coste and Laflamme,* who have during the progress of their several explorations made critical and extended examinations of the relations existing between many outliers of Palæozoic strata and the subjacent Archæan rocks, clearly shows that the mammillated surface long antedates the glacial epoch, and was as characteristic of the surface upon which the earliest Palæozoic sediments were deposited, as that upon which the great glacier rested in glacial times. The chief cavities, vertical precipices and deep, narrow gorges must have been determined by great transverse or lateral breaks. The causes which operated in their formation must have been in force with marked intensity long before the deposition of the Niagara, for as has been shown, the valley had been practically completed before the deposition of these sediments. The rounded contours of the rocky plateau and the intervening hollows doubtless represent the depth to which these crystalline rocks had undergone disintegration during the immense lapse of time while they were exposed to the action of the weather and other denuding agencies before the glacial epoch, while the ice simply removed the loose material resulting from such decomposition, smoothing and striating the rocky surfaces encountered.

Both quartzite and diabase, and sometimes also the massive slate (or greywacké) which occurs as a transition between the more fissile slate beneath and the quartzite above, frequently form cliffs from fifty to two hundred feet in height, the angle of slope being considerably lessened by a talus of angular blocks detached from above. Good examples of these quartzite cliffs are furnished by the shores on the west side of Lake Timiskaming, opposite Bryson or Moose island, at the Obisaga narrows on Lady Evelyn lake, as well as by the steep hills on the west side of Cliff lake, while the Manitou or Devils Rock on the west side of Lake Timiskaming, south of Haileybury, and the western shore of Timagami lake, opposite the Hudson's Bay post, are excellent instances of the vertical precipices produced by exposures of diabasic rocks. Prominent cliffs formed of the massive slate or greywacké may be noticed on the Matabitchouan river immediately above the Fourth Bass lake, as also on the west shore of Lady Evelyn lake, south of Wendabin bay. The action of the frost and weather is continually loosening large masses of these cliffs, which then fall with a great noise, and this phenomenon is so frequent that one of the lakes (Manito-peepagee), to the west of Lake Timagami, has received its name on the supposition that the Evil One was the cause of the disturbance.

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*Bull. Geol. Soc. Am., vol. I, pp. 163-173, also Annual Report, Geol. Surv. Can., 1882-83-84, part D.

Soil.

Although the district as a whole cannot be said to be suitable for agricultural purposes, still in many places considerable areas of good land are known to exist. The largest continuous tracts of such land are to be found in the vicinity of the northern portion of Lake Timiskaming on both sides of the lake, and thus both in Quebec and Ontario, although the larger proportion is in the latter province. The Crown Lands Department of Quebec has subdivided the two townships of Guigues and Duhamel and portions of four others, Fabre, Laverlochère, Baby and Neudlac. These by no means exhaust the arable land on this side, but are sufficient for the present requirements of settlement. On the opposite shore of the lake Ontario has laid out and divided into lots twenty-five townships which extend along the western side of the lake, and running in a northwesterly direction include the valleys of Wabi creek and the Blanche as far as Round lake. Only five of these townships and the southern portion of four others are included within the area covered by the accompanying map.

The area thus subdivided is in general composed of level or slightly rolling clay land. In some places the clay sub-soil is overlain by clay loam or sandy loam, while in other instances a rather barren yellow sand appears at the surface. In the province of Quebec, where the surface has in many places been almost completely denuded by repeated forest fires, this clay is best seen. From the Quinze river, a little south of Quinn point, large areas are covered with a thick mantle of stiff grey clay through which protrude exceedingly rough and prominent hills of quartzite, granite, diabase and breccia-conglomerate. These hills rise abruptly from an otherwise level clay plain, for the surface characterized by the presence of this clay exhibits a singularly flat appearance with only a gentle rise towards the base of the hills.

On the Ontario side the township of Lorraine is rough, rocky and broken, and for the most part unsuitable for farming purposes. Along the valleys and in the vicinity of Lake Timiskaming the soil is clay but these clay flats are of comparatively small extent. To the northwest, however, in the townships of Bucke and Dymond there are quite a number of farms, and a large area of cultivable land exists, so that the villages of Haileybury and Liskeard seem destined to become the centres of a considerable agricultural community.

The top of the limestone plateau which constitutes that portion of the Niagara outlier forming the promontory dividing the northern end of the lake is generally overlain by a light sandy loam soil, although in many places the underlying rock is destitute of any such covering. In the southwestern part of Dymond and the southern portions of Hudson and Henwood a series of rocky ridges of the Huronian slate occur. In the township of Henwood these ridges have a general north-and-south trend; while in the township of Hudson the slate rises into hills some of which are nearly 200 feet in height. North of these ridges, according to Mr. Hermon, the soil is white clay, the surface generally level and the appearance of the country flat and swampy.

Between Mattawa and North Bay, to the south of the Mattawa river, in the townships of Papineau, Calvin, Bonfield and Ferris, considerable areas of land exist which may be utilized for farming purposes, and their proximity to the line of railway makes these of value. Already these townships contain a large number of excellent farms and the region is rapidly becoming settled. The soil is usually a clay-loam, rather rocky and stony in places, but seems to yield excellent crops. In the vicinity of North Bay the land is sandy and light.

The valley of the Sturgeon, below the Timagami river, contains many wide and extensive flats which are susceptible of improvement, but above this stream the valley is much contracted and the flats decrease both in number and extent as the river is ascended, and towards the mouth of the Maskinongé river the country becomes much more broken and for the most part poor and rocky. Between Smoky falls and the mouth of the Timagami, the country in the vicinity of the river is tolerably level and composed of grey clay overlain by sand. The soil is for the most part a sandy loam and affords support to a thick growth of hardwood and evergreens, which by their sturdiness attest the good qualities of the soil beneath. Clearances have been made at intervals along the river, with the exception of that portion flowing through the Indian reserve, as far as the mouth of the Timagami. A short distance below the mouth of the Pike river, on the south side of the river, is an extensive farm cultivated for many years for the purposes of supplying the lumbering camps of Mr. J. R. Booth, and a road connects this depot with the Canadian Pacific railway at Cache Bay station.

To the west of Sturgeon Falls there are a large number of farms which continue up the valley of the Veuve river, almost as far as Warren station, where the valley becomes very narrow. The soil throughout the valley is a stiff grey clay, and as the vegetable mould overlying has been burnt off it has a tendency to cake in dry weather.

In the vicinity of Sturgeon Falls the soil is very sandy, but the clearances continue to the east as far as the boundary of the Indian reserve, and to the south almost to the lake shore, although the land in general in this direction is flooded during the spring freshets.

On the Montreal river, above Bay lake, there are large areas of arable land, especially between Bay lake and the Mattawapika. The region to the northwest is very flat and level, underlain by clay, and although swampy at present would probably be easily drained or dry up when cleared. These areas are most likely continuous with similar tracts noticed to the southwest of the townships of Henwood and Hudson.

A large tract of country extends from the vicinity of North Bay and the southern part of the townships of Widdifield northward to the Opimika creek. The soil is in places sandy and in some spots considerable clay is present, but the whole of this stretch of country is covered by a mixture of hardwoods and evergreens, thus denoting a rather good soil beneath. The greater portion of the district, however, is extremely rocky and barren, the level areas being chiefly occupied by swamps, many of which would be difficult to drain, while the area thus drained would in most cases be insufficient for purposes of farming. Of the country surrounding Timagami lake and the greater part of the central portion of the area only small tracts would be available for purposes of settlement. The soil in general is extremely light, and without the aid of artificial fertilizers would soon fail to yield any adequate return. The rosy picture too often drawn of immense tracts of land available for agricultural purposes is to say the least very misleading, for apart from possible mining and its timber resources, by far the greater portion of the region will only be valuable as a health and recreation ground for tourists and sportsmen. The great tracts of forest as yet untouched by the axe, the vast number of picturesque lakes, both great and small, with fish and game in abundance, seem to render the district especially attractive for such purposes.

Climate.

In regard to the climate of the district as a whole, it may be said in a general way that the advent of spring is from three weeks to a month behind that of the region immediately surrounding the city of Ottawa, with a correspondingly earlier setting in of the winter. The winter is as a rule one of long continued and severe frosts, while the summer is proportionately shorter and much cooler than the country bordering the lower Ottawa. The average fall of snow in winter, as well as the rainfall during summer, is likewise considerably in excess of that in regions farther to the south.

Navigation generally opens on Lake Timiskaming about the end of the first week in May, although in occasional unfavourable seasons it is sometimes delayed a few days longer, while Kipawa lake does not usually break up until a week later. In 1893 the ice on the latter lake broke up and moved out between the 15th and 17th of May. Lake Timagami, which occupies the height-of-land between the waters flowing to Lake Timiskaming and those emptying into Georgian bay, being nearly 400 feet above the last-named lake, does not generally break up until the latter part of May, the lake usually being clear of ice about the 24th of May. The season of navigation closes, as far as Lake Timagami is concerned, between the 10th and 15th of November, while on Lake Timiskaming steamers have been known to make fairly regular trips within a few days of Christmas, although as a rule these boats cease running early in December.

The snow begins to melt about the middle of April, and has generally all disappeared by the 10th of May, although both snow and ice were noticed in secluded nooks and cracks along the sides of the precipitous cliffs on the west side of the Ottawa river as late as the end of May. Mr. C. C. Farr, formerly of the Hudson's Bay Company, and now postmaster of Haileybury, who has become identified with this young and flourishing settlement, states that 'seeding-time commences about the first week in May and ends, so far as oats are concerned, about the fourth of June, though oats have been sown as late as the 20th of June, and have done fairly well. Potatoes can be planted as late as the 20th of June, and it does not profit much to put them in before the 24th of May. Corn, cucumbers and melons can be sown about that date. Haying commences about the 14th July, harvest the 15th August.'

Summer frosts, so much dreaded by the farmers, especially in districts newly opened for settlement, have in the past proved a rather serious barrier to the successful raising of wheat, while oats have suffered severely, particularly in clearances situated some distance from the larger bodies of water. Frosts generally occur from the 18th to the 25th of August on the calm, clear nights following heavy north winds. In the vicinity of Lake Timiskaming the settlers often escape them altogether on account of their proximity to this large sheet of water, or their crops are but slightly injured, the more tender vegetables frequently being the only sufferers. The gradual clearing up of the land and the draining of many of the swamps will, however, materially mitigate this difficulty, particularly in the district in the vicinity of Lake Timiskaming, which is the area most suitable for extensive settlement.

The Native Inhabitants.

The Indians who reside within the area under description belong to the once numerous and powerful Algonquin family. They speak the Otchipew or Chippewa language, the same as that in use among the many bands which are scattered over the wide territory to the north and west of Lake Superior, with only a few minor alterations. They are divided into three bands known respectively as the Nipissing, Temiscamingue and Temagamingue bands. On June 30th, 1887, the census taken by the Department of Indian Affairs showed a total Indian population of 394, while on June 30, 1897, this population had only been increased to 430. The census taken in 1887 showed the following numbers in each band, Nipissing 165, Temiscamingue 136, and Temagamingue 93, while that taken in 1897 shows the population of the several bands to be, Nipissing 193, Temiscamingue 162, and Temagamingue 75. While, therefore, the total Indian population of the district shows a slight increase, one of the bands (Temagamingue) is slowly but surely decreasing. Two of the bands are comfortably settled on spacious reserves, but no tract of land has yet been allotted to the Temagamingue band. The Nipissing band resides chiefly in two small villages situated on the north shore of Lake Nipissing. The larger of these is about two miles west of North Bay to the south-west of Beaucage station on the Canadian Pacific railway, while the smaller one is located near the western boundary of the reserve, about four miles southeast of Sturgeon Falls. The Indians and associated half-breeds have built a considerable number of rather substantial dwellings, each with a small cultivated patch attached, on the northern bank of the Quinze river, forming the village or settlement of North Timiskaming.

Timber.

All the early explorers speak in terms of enthusiasm of the original great forests of the region here described. The most valuable tree from a commercial standpoint is the white pine (*Pinus strobus*), and in spite of the extensive operations carried on almost uninterruptedly by the lumbermen throughout a large part of this region during the past fifty years this tree is still present in considerable quantity. Next in importance and more abundantly distributed is the Norway or red pine (*Pinus resinosa*). In the early years of the lumber trade the greater value of this tree caused it to be sought for at more remote distances than the white pine, and thus we find at this time that camps for cutting red pine timber were many miles in advance of those erected for the purpose of securing white pine logs. The superior qualities of the white pine, however, soon came to be recognized and in time completely drove the red pine from the market, or so limited its sale that only a few of the finest trees were hewed down and utilized. Of late years, however, the marked diminution in size and quantity of the white pine has again brought the red pine forward, and both varieties are now cut without discrimination. The red pine seems to flourish on the apparently sterile sand plains, which are a feature in many parts of this district, and frequently forms exceedingly thick groves on the sides of hills where sand and gravel have collected, or on points composed of these drift materials which jut out into many of the lakes.

Jackpine, called by some pitch-pine, or bastard spruce (*Pinus banksiana*), is very often encountered in the more barren and rocky areas, and its presence seems an almost certain indication of the extreme poverty of the underlying soil. It is usually more or less scrubby or stunted in its growth, although occasionally, as in some areas to the northwest of Lake Timiskaming, it attains sufficient dimensions to be utilized for rough lumber. In the vicinity of the southern and eastern shores of Lake Nipissing the scanty groves of dwarf-like evergreens are almost wholly composed of this species, the hardy roots penetrating the various cracks and crevices of the rock. This tree also seems to select sandy or gravelly plains which have been overrun by fire and which had previously been occupied by a luxuriant growth of red or white pine.

Both white and black spruce (*Picea alba* and *Picea nigra*) are frequently met with, the latter being more abundant, but are too small to be of any commercial value for lumber, although many individuals would make excellent masts or spars.

White cedar (*Thuga occidentalis*) is usually found fringing the banks of streams or the shores of lakes, where it often forms a thick and at times an almost impenetrable undergrowth. Overhanging trees are frequently undermined by the waters or current during times of high water, and thus it happens that most of the drift-wood encountered belongs to this species. Its favourite haunt also seems to be the marshy hollows or flats which so commonly occur between the rocky hills, and extensive areas of swamps are almost entirely covered with a dense forest of this tree. As a rule the tree is small and more or less stunted in its growth, while the larger individuals are frequently hollow at the butt. To the north and northwest of Lake Timiskaming many fine speciments of this tree were noticed.

The white or canoe birch (*Betula papyrifera*)is also of very common

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occurrence, and together with the aspen poplar forms the prevailing second growth in areas which have been recently swept by fire. Both species in these instances form very thick groves of tall and straight though small trees. Interspersed with the more prevalent evergreen, especially where the soil is deeper and better, are occasional large trees which are of sufficient size to furnish good bark for canoes, as in the Sturgeon River valley, where good sized specimens may still be procured. The birch-bark canoes made on Lakes Nipissing and Timagami and at Mattawa have always been considered the very best of their kind both in build and material, but of late years the supply of good and suitable bark is becoming perceptibly less.

Three varieties of the poplar were noticed throughout the region, the balsam or rough-barked poplar (*Populus balsamifera*), the white or aspen poplar (*Populus tremuloides*) and the large toothed poplar or aspen (*Populus grandidentata*). The poplar sometimes forms stately trees, especially in the Sturgeon River valley and in the country to the north and northwest of Lake Timiskaming. Tamarack, sometimes called hackmatack and occasionally juniper, (*Larix americana*), is abundant, and in common with the cedar, and in a lesser degree the spruce, affects the low-lying areas or those portions of the forest where moisture may be readily and constantly secured. The immense tracts of swampy land between the headwaters of the Tomiko and Ottertail rivers to the north of the Spruce lakes contain an abundant supply of good sized specimens of this tree, and it is constantly met with all through the region whenever the conditions are favourable to its growth.

The balsam or fir (*Abies balsamea*) is one of the most common in the moist areas. Hemlock (*Tsuga canadensis*) was noticed northward to the Indian portage-route to Kipawa lake, a short distance below the mouth of the Kipawa river, but no specimens were observed as far north as the Old Fort narrows. It occurs rather abundantly and of large size in the vicinity of Lake Nipissing and on the Sturgeon river, but was not remarked in the northern and northwestern portions of the region. The basswood or linden tree (*Tilia americana*) was occasionally noticed on the Sturgeon river, while Sir William Logan mentions individuals two feet in diameter, associated with black birch and maple of similar dimensions, in the hardwood strip of country extending from behind the hills north of Trout lake at the head of the Mattawa river to the Opimika narrows on Lake Timiskaming. The basswood was also noticed mixed with maple, elm, poplar and balsam near the mouth of the Blanche at the north end of Lake Timiskaming.

The American yew, sometimes called ground hemlock (*Taxus baccata* var. *Canadensis*), is an exceedingly common shrub, and is particularly noticeable, as when present it often forms an almost impenetrable underbrush. Alder and willow of several varieties are present in the various swamps or lining the banks or shores of streams and lakes.

Although nearly all the principal varieties of hardwood are found in this region the proportion which such trees bear to timber of a softer description is quite insignificant. Of the maple family perhaps the most abundant is the sugar maple (*Acer saccharum*), which is frequently of large dimensions. The soft maple (*Acer rubrum*) is also present in large quantities, but the black or bird's eye maple (*Acer nigrum*) is only rarely met with in the valleys of the southern portion of the region. The mountain maple (*Acer spicatum*) is one of the common varieties in moist ground, while the striped maple (*Acer pennsylvanicum*) was noticed in many places. This tree is often called moosewood, because the green and juicy tops form a favourite food for the moose, although the true 'moosewood' (*Dirca palustris*) was noticed in many places suitable to its growth.

Large trees of yellow birch (*Betula lutea*) were remarked throughout the region, especially in the vicinity of the northern end of Lake Timiskaming, while specimens of the black or cherry birch (*Betula lenta*) were seen over thirty inches in diameter in the region to the north of the Mattawa river. The blue oak or swamp white oak (*Quercus macrocarpa*) is the most abundant of the oak family, and its favourite haunt seems to be the alluvial flats or intervals along the banks of streams where the soil is sufficiently moist and fertile. Here it is associated with the white elm (*Ulmus americana*), which forms large and beautiful trees, and the black or water ash (*Fraxinus sambucifolia*). The white oak (*Quercus alba*) seems to delight in lighter and drier soil, and good specimens were seen growing in the vicinity of Fort Timiskaming. The red oak (*Quercus rubra*) was also noticed in places as far north as our explorations extended. Ironwood (*Ostrya virginica*) is tolerably abundant and good. Specimens were noticed growing with the American beech (*Fagus ferruginea*) in the strip of hardwood land about five miles west of the Opimika narrows on Lake Timiskaming.

Of the wild fruits the thimble berry (*Rubus villosus*) is only very sparingly represented, if at all, in the southeastern portion of the district on the Ottawa, but the red raspberry (*Rubus strigosus*) is abundant on all neglected clearings, or in areas which have been burnt, and in the vicinity of deserted lumber camps. The wild grape (*Vitis riparia*) was seen growing on Mann island, Lake Timiskaming, as well as on several islands of Lake Nipissing. Both varieties of the low-bush cranberry (*Oxycoccus macrocarpus* and *O. vulgaris*) are found on many of the marshes which are so prevalent around Lake Nipissing. The former species is the variety generally collected, and the extensive swampy flats in the vicinity of the mouth of the Sturgeon river on Lake Nipissing are the principal localities for these berries. They formerly were a source of considerable revenue to the thrifty Nipissing band of Indians, who took them in barrels down to the French river to sell to the traders on Lake Huron. Several barrels of the smaller variety of cranberry (*O. vulgaris*) were sent to Toronto, but did not command a sufficient price even to pay expenses.

The high bush cranberry (*Viburnum opulus*) grows in damp ground along the river-valleys or on the margins of lakes where the shores are low. The bushes are sometimes between ten and twenty feet in height, and are especially abundant on Devil channel at the head of Lake Timiskaming, on the shores of Mann island in Lake Timiskaming, and fringing the banks of the Little and Ottertail rivers farther to the south. The two varieties of blueberry commonly met with (*Vaccinium canadense* and *V. corymbosum*) are present on all surfaces which have been lately swept by fire, and the Indians have been known to set fire to some of the smaller islands in order to get a supply of this fruit. *Vaccinium canadense* prefers the drier and more rocky locality, but is also frequently noticed in swampy flats directly exposed to the sun's rays, while *Vaccinium corymbosum* with less abundant though much better and larger fruit, prefers a deeper and richer soil as well as localities which are more in the shade.

Fauna.

Of the deer tribe the most abundant are the moose (*Alce americanus*) and the red or Virginia deer (*Virginianus cariacus*). Owing to the recent provisions made by the Ontario Government looking to their preservation, aided no doubt by the advance of settlement to the south, these animals have become exceedingly numerous. The moose in particular is abundant, and their 'runways,' especially in the vicinity of rivers and lakes off the frequented routes of travel, are usually better beaten than many of the cattle paths in the neighbourhood of considerable settlements. This is notably the case on the Ottertail river, which flows into Lake Timiskaming from the west about four miles above the Opimika narrows on the small stream connecting Boice and Wicksteed lakes, as well as on the lower part of the Montreal river. It is only within the last ten years that the red or jumping deer have become at all numerous, and before 1887 only occasional specimens were shot, but now every sandy beach in the more secluded portions of the region is covered with the imprints of the feet of these animals.

The wolf (*Canis lupus*) has likewise become rather common, although a few years ago it was rarely if ever encountered. This animal follows very closely the migrations of the deer.

Both moose and red deer are gradually moving northward and northwestward, the former being met with in the vicinity of Abitibi lake where previously they were unknown, while occasional specimens have been shot, according to Mr. A. P. Low, close to Moose Factory on James bay.

The woodland caribou (*Rangifer caribou*) is not at all abundant, and chiefly inhabits the region to the north and northeast of Kipawa lake, becoming more numerous to the northeast. The black bear (*Ursus americanus*) is still a rather common animal, but the constant demand for and ready sale of the skins has led to their diminution.

Specimens of the fox (*Vulpes vulgaris*) are encountered and the skins find a ready sale. The Canada lynx or wild cat (*Lynx canadensis*) is likewise found, but only occasionally. The otter (*Lutra canadensis*) and the beaver (*Castor fibre*) are fast becoming extinct in this region, although signs of their presence may still be seen on many of the less frequented streams and ponds.

The fisher (*Mustela pennantii*), the sable or marten (*Mustela americana*), the stoat or ermine (*Putorius ermineus*), the mink (*Putorius vision*), and the muskrat (*Fibre zibethicus*) are also met with, and the two last-named are still abundant in the region. The skunk (*Mephitis mephitica*) is very common, especially in the vicinity of the settlements or lumber camps, where they come to feed on the rubbish thrown from the kitchen.

The porcupine (*Erethizon dorsatus*), ground hog (*Arctomys monax*) and the hare or rabbit (*Lepus americanus*) are also common. The chipmunk or striped squirrel (*Tamias striatus*), the red squirrel or chickaree (*Sciurus hudsonius*) and the flying squirrel (*Sciuropterus volucella*) are likewise common throughout the district.

No special attention was devoted to noting the presence or habits of the birds of the district, but a few observations regarding the most noticeable ones may be of interest. Ducks are as a rule comparatively scarce throughout the greater part of the area, chiefly because of the marked absence of wild rice, their favourite food, and the somewhat rare occurrence of open marshes, their customary habitats. There are, however, several very notable exceptions to this rule, and the shallow swampy bays which characterize the west portion of Lake Nipissing, the northeastern extremity of Shabosagi or Wicksteed lake, as well as the northern end of Lake Timiskaming, are favourite resorts for a rather large number of ducks during certain months both in the spring and autumn. During the summer months it sometimes happens in passing over the less frequented routes that occasional specimens of the black duck (*Anas obscura*) and the wood duck (*Aix sponsa*) are met with.

The merganser or saw-bill (*Merganser americanus*) is a very familiar sight along the numerous waterways, especially at the foot of small rapids.

Occasional specimens of the pied-billed grebe or dabchick (*Podilymbus podiceps*) were also met with. The great northern diver or loon (*Urinator imber*) is also a common inhabitant of the district. With few exceptions each of the small lakes has a pair of these birds, while in the larger expanses of water every individual bay or arm contains two loons, who year after year return with great regularity to the same locality for breeding purposes.

The osprey (*Panidion haliäetus carolinensis*) was frequently noticed, the nest being usually situated on the very summit of a lofty white pine 'rampike.'

The herring gull (*Larus argentatus smithsonianus*) is also one of the most abundant birds of the lakes of this region. Its nesting place is usually on bare rounded hummocks of rock, almost completely destitute of soil or vegetation.

The raven (*Corvus corax principalis*) very often builds on the inaccessible ledges of the high rocky perpendicular cliffs. Some of the principal localities where these birds have nested from year to year are—the Roche à Corbeau and 'The Canal' on Lake Kipawa, the west side of Lady Evelyn lake, the Crow Rock in the northern part of Annima-Nipissing lake and other places where the cliffs are high and sufficiently steep. The belted king-fisher (*Ceryle alcyon*) is constantly seen along the margins of creeks and rivers. The ruffed grouse or birch partridge (*Bonasa umbellus togata*) is very common, as is also the Canada grouse or spruce partridge (*Dendragopus canadensis*). Both the white ptarmigan (*Lagopus lagopus*) and rock ptarmigan (*Lagopus rupestris*) are also occasional visitors to this district.

Fish are exceedingly abundant in nearly all the lakes. The largest fish met with is perhaps the lake or rock sturgeon (*Acipenser rubicundus*) although many individuals of the lake trout nearly equal the sturgeon in size. The sturgeon was formerly a rather abundant inhabitant of Lake Nipissing, but of late years, owing doubtless to the increase in the number of settlers, is less common there.

From an economic standpoint, however, the lake trout (*Salvelinus namaycush*) and the whitefish (*Coregonus clupeiformis*) are the most important, as they are not only abundantly and widely distributed throughout the larger lakes of the district, but form a usual and valuable article of diet among the scattered settlements. Both these fish, although present in considerable quantity in Lake Nipissing, attain their largest dimensions in the clear depths of Lake Timagami. There are no trout in Lake Timiskaming or the Ottawa river or even in Lake Kipawa, although most of the lakes immediately tributary to these contain abundant and fine specimens of these fish. The brook trout (*Salvelinus fontinalis*) although comparatively rare is rather widely distributed, and its presence in any stream or lake is a sure indication of unusually clear and cold water. The small lakes to the west of the Mountain rapid on the Ottawa contain them in abundance, while they are exceedingly numerous in the Opimika creek and the lakes which this drains, especially Emerald lake. Latour creek, which empties Trout lake, in the township of Lorraine on the west side of Lake Timiskaming, has always been a favourite fishing resort for the inhabitants of the Hudson's Bay Company's old post, although the largest and finest specimens of this fish in the whole region may be procured in the streams entering Willow Island lake to the west of Lady Evelyn lake.

Closely allied to the whitefish is the fresh-water or lake herring (*Coregonus artedi*), which is somewhat abundant in many of the lakes.

Next in importance to the trout and whitefish are the various species of bass and sunfish which, with the exception of the black bass, do not attain to any great size. The black bass are of excellent quality and exceedingly plentiful, these fish being found in most of the lakes comprised within the area of the map-sheets. Both species, the large-mouthed and small mouthed, (*Micropterus salmoides* and *M. dolomieu*) are present. There is an extreme variability in point of colour which is clearly owing to the nature of their surroundings. In lakes and streams where the water is of a prevailing brownish tint the bass have a correspondingly dark hue, while in the clear, greenish water of Lake Timagami and Little lake, to the east of the Old Fort narrows, the bass have a pale-green coloration. This variation in hue is not a peculiarity affecting the bass alone, but may be also noticed in the trout, pike and especially in the pickerel. The finest specimens of these fish may be secured in Lady Evelyn lake (which contains no trout), Timagami, Red Cedar, Annima-Nipissing, Whitebear, Net and Rabbit lakes, although these by no means exhaust the list; while on Lake Timiskaming and Little lake, though not so abundant, the specimens obtained are generally of very large size.

The rock bass or red eye (*Ambloplites rupestris*) and the common sunfish (*Lepomis pallidus*) are also extremely numerous where conditions are favourable.

The common yellow perch and the pike-perch or pickerel are closely allied forms. The yellow perch (*Perca americana*), although of good quality is generally small, rarely attaining over one pound in weight, while the average size is very much smaller. It is not of economic importance as a food fish like the pickerel. The pickerel (*Stizostedium vitreum*), called by the French doré, is possibly next to the trout and whitefish the most valuable food fish found in the region. During several weeks of summer (generally in August) these fish retreat to the deeper water of the lakes, but at other times they may be readily secured in large numbers either by means of nets or with hook and line. At the Old Fort narrows on Lake Timiskaming it is by far the most abundant fish. It is also present in most of the other lakes throughout the district, especially in Lakes Kipawa, Obashing and Timagami The general weight is from four to seven pounds, but one caught by us on White-bear lake weighed fifteen pounds, while another from Hunters Lodge narrows on Lake Kipawa measured twenty-seven inches in length.

Both the common pike (*Esox lucius*) and the great pike or maskinongé (*Esox nobilior*), are found, although the former is by far the more abundant. The pike is a very common inhabitant in nearly all the lakes, while the maskinongé is comparatively rare, although several individuals were caught at the Old Fort narrows on Lake Timiskaming.

The common eel (*Anguilla rostrata*) is also present in many of the lakes, particularly Timiskaming and Timagami. Other fishes which might be mentioned are several species of sucker, the common cat-fish (*Amiurus nebulosus*) and the silver chub (*Semotilus corporalis*) but none of these are of economic value.

While most of the lakes are very abundantly supplied with fish there are some which deserve special mention. Timagami, Annima-Nipissing, White-bear and Rabbit lakes are *par excellence* the waters in which both trout and whitefish are found in greatest quantity and best quality, while the bass, pickerel and pike are also of large size and excellent quality. Lady Evelyn and Timiskaming lakes contain no trout. The Opimika and Old Fort narrows on Lake Timiskaming have always been and still are excellent fishing places, the fish chiefly caught being pickerel, pike and bass. Pickerel are caught in great numbers in the spring above the dam on Lake Kipawa near the outlet of the Kipawa river, as well as Hunters Lodge narrows, while the Narrows on Obashing lake is also a favourite resort for these fish.

GEOLOGY.

GENERAL STATEMENT.

The several geological systems and formations represented in the region covered by the accompanying map-sheets and subjacent to the Pleistocene superficial deposits may be thus stated in descending order:—

PALÆOZOIC
SILURIAN—*Niagara.*
CAMBRO-SILURIAN—*Trenton.*
Birdseye and Black river.

ARCHÆAN
HURONIAN,
LAURENTIAN—*Diorite-gneiss and granite-gneiss or "Fundamental gneiss."*

The Archæan rocks of the region here described may naturally be separated into two great subdivisions, that of the so-called Lower Laurentian and the Huronian, although a few small isolated inliers of crystalline limestone, and one at least of a dark-grey, exceedingly squeezed and altered gneissic rock are found to be enclosed in the ordinary granitic and dioritic gneisses. These are unimportant in this district, and so small in area that it has not been possible to distinguish them separately on the map. They resemble very closely rocks which in regions farther to the south and southeast are known as the Grenville series. The present report, therefore, does not include any discussion of the relations of the rocks classed as Huronian with those of the Grenville series. These two series do not come in contact in this area, and the question of their relations is at present being made the subject of special investigation in central Ontario.

Under the name Laurentian, in the area here described, are included a great number of varietal forms of granitic and dioritic materials, having essentially the chemical and mineralogical composition of such rock-types, but differing in their foliated texture, a difference which although almost invariably present is sometimes obscure and occasionally fails altogether. Their subdivision in the present report is based solely on their petrographical and mineralogical characters, for although their prevailing foliation, frequently marked by alternating bands of varying composition and colour, resembles in some respects an original stratification, it has been found impossible to make any such stratigraphical subdivision corresponding to that of later and truly bedded formations.

Detailed investigations both in the field and with the microscope, by various geologists and petrographers, have of late led to the belief that most of these gneisses have an origin in common with their more massive equivalents, and that the prevailing foliated character has been imparted to the rock-mass by differentiation in a slowly cooling magma of more or less heterogeneous composition, or as a result of deformation by pressure after the rock had undergone either partial or complete consolidation. The cogency of the arguments which have been urged in favour of the recognition of the greater part, at least, of these rocks as foliated irruptives now seems beyond question.

Every recent report aiming at scientific accuracy is necessarily prefaced by an apology or explanation of the use of the term Laurentian to include such gneissic rocks of irruptive origin, that have been in a molten or plastic condition at a time subsequent to the deposition and hardening of later truly stratified rocks with which they are intimately associated and occasionally interfoliated.

It must, therefore, be clearly understood that in placing the rocks here representing the Laurentian at the base of a table such as that just given it is not intended to indicate that they stand for any distinct or prolonged lapse of geological time, nor to affirm that these rocks as a whole, in their present condition, and with the foliation they now possess, really antedate those of the Huronian system. This, it will be shown, is not the case in many, if not in most instances where a question of the kind can be determined.

The fundamental gneiss is here, therefore, accorded a priority in description to which it is not structurally entitled, as it may possibly represent in great part the first-formed crust of the earth, which, necessarily thin and fragile, and so liable to frequent upwellings of the molten mass beneath, has undergone successive fusions and recementations before reaching its present condition. As at present mapped it is regarded as a complex of irruptive plutonic rocks, representing repeated and intricate intrusions of basic and acidic material. Although in many instances, and in limited areas, the succession of such irruptions can be ascertained with tolerable accuracy, any attempt to correlate this succession in detail over extended areas has invariably ended in more or less complete failure.

In general, however, it may be stated that the earliest secretions of the magma from which these rocks have solidified consisted of a series of granitic and dioritic gneisses, very evenly and distinctly foliated, varying in colour from reddish through reddish-grey and grey to dark green and almost black.

These gneissic rocks were subsequently invaded by a massive, deep-red biotite-hornblende-gneiss that usually possesses a more or less distinct foliated structure, marked by the parallel alignment of the bisilicate minerals. It seems highly probable, however, that no great lapse of time intervened between these successive irruptions, as the latter in all probability represents the residual portion of the magma, necessarily more acidic and homogeneous in composition. Dikes of coarse pegmatite, as well as of fine-grained aplite, cut the different varieties of gneissic rocks or are frequently interfoliated with them.

To the northeast of Lake Timagami there is a large area of flesh-red granite which in many places, especially in the vicinity of Carrying and Annima-Nipissing lakes, has a distinct foliated structure. In appearance, composition, and behaviour it has so close a resemblance to similar rocks mapped as Laurentian farther to the south that it is proposed to include it with these rocks.

Between Timagami and Rabbit lakes there is a somewhat similar granite, which, however, is continuous with the main Laurentian area to the south, and is accordingly designated by the same coloration. In both cases these rocks pass by insensible gradations into a medium-textured dark-green gabbo or gabbro-diorite, with which they are intimately associated, by an increase in the plagioclase and the preponderance of hornblende as the coloured constituent. Although in the accompanying map these gabbro masses are shown in the colour usual for such basic intrusions it must be borne in mind that they are believed to represent basic portions or segregations of the same magma that has elsewhere crystallized as granite.

The Huronian rocks are generally clastic in composition, appearance, and microscopic structure, and in this respect are in marked contrast, even in their most altered phases, to those described as constituting the Laurentian of the district. A large proportion of these stratified rocks indicate the existence of intense and widespread vulcanism, which evidently characterized this period; their composition and structure showing a most intimate association of undoubted volcanic ejectamenta with material resulting from the ordinary processes of erosion and sedimentation. The breccia or breccia-conglomerate which is so abundantly represented, and here forms the basal member of the Huronian, is composed chiefly of angular, sub-angular, or rounded fragments of red grey granite, diabase of different degrees of texture, and various fine-grained slaty and hälleflinta-like rocks, embedded in a fine-grained, often argillitic matrix, consisting of similar material in a much finer state of division, with chlorite and sericite filling the smaller interstices.

In earlier reports on these rocks the much greater relative abundance of the granitic fragments, coupled with the somewhat distinct foliation observable in a few of these, was evidently taken to be sufficiently strong and positive evidence to justify their description as strata resulting from the degradation of the Laurentian gneisses and granites. The more detailed and critical examinations made during recent years, covering the country between Lakes Huron and Timiskaming, show, however, the error of such a conclusion in any wide or general sense. Thus the rock first described under the name of 'chloritic slate-conglomerate' by Sir William Logan must be regarded as essentially of pyroclastic origin, the volcanic ejectamenta having been evidently spread out upon the bottom of a shallow sea, where they have undergone in many instances considerable attrition and re-arrangement by water. Much of the coarser material cannot be correlated with anything now known to be present at the earth's surface in this region; while the intimate association of this rock with diabase and gabbro intrusive masses, rather than with the granites, reveals a close genetic relationship subsisting between these rocks that cannot be regarded as merely accidental.

Throughout the area, the Huronian, where fully represented, is separable into three distinct subdivisions which are, in ascending order, as follows:—(1.) *Breccia or breccia-conglomerate.* (2.) *Greywacke shale or slate.* (3.) *Feldspathic sandstone or quartzite.*

As a rule the lowest number, or breccia-conglomerate, presents only obscure evidence of stratification, and wherever such was visible the rock occurs in thick massive beds showing only a slight inclination or dip. This may be well seen in the hills on either side of Lake Timiskaming between the Montreal river and the Old Fort narrows. Where subjected to pressure, however, as is very frequently the case, the cleavage-foliation thus developed is a much more prominent structural feature and is thus very often mistaken for the bedding. This is especially the case in the region immediately adjacent to Lake Timagami where this rock is very widely exposed, and where it is associated with and squeezed between large masses of diabase and granite.

Superimposed upon this, and forming a transitional rock upwards into the succeeding subdivision, are beds of varying thicknesses of greywacke or feldspathic sandstone, less massive in structure while the coarser fragmental material gradually disappears as an ascent is made in the series. The succeeding shale or slate, which is in general very similar in composition to the greywacké or the finer matrix of the breccia-conglomerate beneath, is often beautifully banded in varying shades of green, purple or brown. The cleavage in most cases corresponds with the bedding, although occasional instances were noticed where cleavage or jointage planes were developed at considerable angles with this bedding. Superimposed on this slate, in many parts of the area, is a very massive much jointed quartzite or grit, generally sea-green in colour because of the abundance of minute scales of sericite distributed through the finer portions of the rock. Occasionally, however, it has a reddish tinge, and the arkose then closely resembles a granite, both in composition and appearance. The rock is so massive that it is often only by the parallel alignment of certain coarse quartzose and other fragments that the original bedding can be distinguished. These various members of the Huronian here follow one another in regular and often nearly horizontal succession, except in the vicinity of the large igneous masses, where they show considerable evidence of disturbance as well as of alteration.

The Palæozoic rocks represented in this area consist of outlying patches of the following formations:—(1) *Birdseye and Black river,* (2) *Lower Trenton,* (3) *Niagara.*

The outliers representing the Birdseye and Black River formation are exposed on some of the islands composing the Manitou group in Lake Nipissing. These are of very limited extent and consist of sandstones, limestones and shales, the whole section probably not exceeding thirty feet in thickness.

Some small exposures of sandstones and arenaceous limestones occur overlying unconformably the gneissic rocks of the Laurentian on the Ottawa river below Mattawa. The fossils secured from these thin exposures indicate that the containing rocks are of lower Trenton age, and thus somewhat higher in the stratigraphical succession than those occurring on the Manitou islands.

The Niagara formation, as exhibited in this district, is composed of light-buff or cream-coloured limestones and shales, with a basal boulder-conglomerate, or sandstone, unconformably overlying the Huronian slates and quartzites on the shores and islands of the northern portion of Lake Timiskaming. The strata composing this formation form a low, shallow, synclinal trough.

The coarser varieties of drift material, such as boulders, gravel and sand, are rather abundantly represented on the higher grounds, the surface being everywhere more or less encumbered with the larger erratics, especially on those slopes facing southward, while the comparatively shallow and rocky intervening valleys are frequently filled with coarse yellow sand, sometimes derived mainly from the decomposition of rock almost *in situ.* These boulders are usually of rock types prevalent in the district, but some show carriage from considerable distances. With the exception perhaps of the Mattawa, Nipissing and Timiskaming valleys there is little or no clay present in this district, the flatter details of topographical outline being given chiefly by deposits of coarse yellow sand. In the Timiskaming valley there is a thick and extensive deposit of a stiff, stratified, grey clay which in many places effectually conceals the rock beneath. This clay occurs in flats of considerable area, through which the various streams have cut deep and tortuous channels, while protruding through these clay plains are steep and rocky hills of the prevailing types of the Huronian strata. In the wide depression, the deepest and most northern portion of which is occupied by the Mattawa river, and which has also been utilized in the construction of the Canadian Pacific railway, the minor valleys, and often too the separating rounded rocky elevations, are covered by clay deposits containing a considerable intermixture of boulders.

In the vicinity of North Bay and Sturgeon Falls a considerable depth of coarse and yellow sand is present at the surface, concealing the grey clay beneath; but at the west of Sturgeon Falls, especially in the vicinity of Verner, the stiff, grey, stratified clay comes to the surface, forming flats which have been burnt over or cleared. So far no fossils have been found in these clays, although in places diligent search was made for any such evidence of their origin, especially in the hard concretionary nodules which may be occasionally noticed.

The areas covered by the several rock formations may be stated roughly as follows: On the Lake Nipissing sheet there are about 3,186 square miles of Laurentian, and 270 square miles of Huronian, while on the Lake Timiskaming sheet there are only 946 square miles of Laurentian, 2,470 square miles of Huronian and associated eruptives, and forty square miles of Silurian. The two sheets combined, therefore, show 4,132 square miles occupied by Laurentian, and 2,740 square miles by Huronian and associated granites and diabases. The Silurian covers about forty square miles, but extends northwestward to a considerable distance beyond the northern confines of the Lake Timiskaming sheet. The aggregate area of Cambro-Silurian strata exposed on Lake Nipissing and Ottawa river is less than two square miles.

LAURENTIAN.

The name Laurentian was originally proposed by Sir William Logan, in 1853, as the most appropriate designation for rocks classified by him in previous reports as the 'Metamorphic Series,' and which were believed to be identical in composition and origin with similar rocks so named and described by Lyell. The term thus introduced soon received an almost universal adoption by geologists, as a convenient one for the gneissic crystalline rocks found to underlie unconformably the Palæozoic strata, and presumably forming the oldest of the geological systems. The urgent need of such a distinctive appellation was recognized as a consequence of the ambiguity which would necessarily arise from the use of such a general term as 'metamorphic,' which is applicable to any group of strata in an altered condition, while the peculiar fitness of the name was suggested by the fact that these rocks were found to constitute the bulk of the Laurentide mountains, a series of elevations lying to the north of the River St. Lawrence, and which were so called by the late Mr. Garneau, the historian, of Quebec.

The term 'gneiss' or 'gneuss' was originally employed by the early Saxon miners for the country-rock containing the Erzgebirge silver ore deposits. The rocks so named were divided into a 'red' and 'grey' variety, which although differing somewhat in their component minerals presented many features in common that caused them to be included under a uniform designation. The rocks so described are closely analogous in composition and structure to many of the rocks within the area of the present map-sheets, and to which the name 'gneiss' has been usually applied. The name was very generally adopted by geologists, and its use was primarily restricted to rocks essentially granitic in their composition and appearance, differentiated solely on account of their foliated texture; the persistency of this peculiar structure over large areas presumably furnishing proof of a difference in origin from the normal or massive type. Gradually, however, the use of the term became so extended as to include a great variety of crystalline rocks differing widely in composition and origin, but which exhibited in common a more or less decided tendency to a parallel arrangement of their component minerals.

Although modern petrographical studies have demonstrated the inapplicability of such a term for purposes of accurate description, except as an affix to denote the structural features of the rock-types examined, the name must still be employed as a convenient 'field' term, as a means of rough description and correlation where detailed microscopic examination is either impossible or considered unnecessary.

The origin of these gneissic crystalline rocks was, for a long time, more or less a matter of theory and conjecture. Previous to the promulgation of the theories regarding rock metamorphism, first held by Hutton and subsequently by Lyell, to whom we owe the first use and definition of this term, these rocks were regarded as portions of the primeval crust, which had either never been enveloped by the later sedimentaries, or from which such covering, if originally present, had been removed as a result of subsequent upheaval and denudation. Such rocks were then almost invariably referred to as the 'Fundamental gneiss or granite' and believed to be the basement or floor upon which all subsequent sedimentary formations were deposited.

Metamorphism, either regional or contact, has always been considered the most potent influence in the destruction of evidence of original structure and composition in rocks subjected to the effect of the earth's internal heat, or that engendered by the proximity of eruptive masses.

The various changes, however, which this term describes, were for a long time thought to be confined entirely to sedimentary strata, while masses of igneous plutonic rocks were regarded as too hard and unyielding to be at all affected by the metamorphosing agencies of even the most profound orographic movements. Foliation, though long held to be entirely distinct from stratification in the case of slaty and other allied rocks, was in the instance of these gneissic rocks regarded as the surviving trace of the parallel structure due to original sedimentation which had escaped obliteration. It is only in very recent years that this impression has been overcome by detailed examination and study, both in the field and with the microscope, carried on by many individual observers in large and widely separated districts, showing clearly that foliation and schistosity cannot be assumed to denote original stratification.

The first really exact and satisfactory account of crystalline schists resulting from the metamorphism of massive eruptives was given as the outcome of the detailed work by Lossen in the Hartz mountains, who, as early as 1872,* directed attention to the deformation of diabases occurring in contact with granites, and showed the close analogy existing between the results of contact and regional metamorphism, as well as the production by metamorphic agencies of a foliated structure not connected in any way with stratification.

The most important contribution, however, in regard to the effects of dynamic metamorphism, appeared in 1884, from the pen of Prof. Johannes Lehmann, who after several years detailed studies on the origin of crystalline schists, based on a very large number of observations made chiefly in Saxony, but also in Bavaria and Bohemia, published his celebrated memoir on this subject.† The conclusion is reached that 'gneiss' is simply a structural form of granular feldspathic rocks, and as such is capable of subdivision according to composition into varieties corresponding with the types of the ordinary massive plutonics, while the prevailing parallel structure may be, but very rarely is, original. He regards these foliated rocks as of igneous origin and not in any way related to sedimentary deposits, the characteristic structure being developed as a result of 'stretching' when the rock was in a solid state. It is further concluded that such rocks become more evenly and finely banded in proportion to the intensity of such 'stretching' action.

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*Zeitschr. Deutsch. Geol. Gesell. vol. XXIV, p. 763, Berlin, 1872.

†Untersuchungen über die Enstehung der Altkrystallinischen Schiefergesteine. Bonn, 1884.

Daubrée was also convinced that the schistose and foliated structures frequently assumed by massive rocks were not connected with original stratification, but secondarily developed as a result of pressure before the rock had wholly solidified. ‡Naumann emphasizes this latter fact, while Reusch, from studies undertaken in the vicinity of Bergen in Norway, also comes to similar conclusions. In England, Teall, from his examination of the metamorphic area in the vicinity of the Lizard in Cornwall,‖ reaches results closely resembling those of Lehmann; while in the United States, in the gabbro area near Baltimore, Maryland, as well as in the greenstone-schist area of the Menominee and Marquette regions in Michigan, the late Prof. Geo. H. Williams has shown the secondary development of a schistose structure in originally massive plutonic rocks.* In Canada, Lawson,† from his examination and studies of the rocks of the Lake of the Woods and Rainy Lake districts, was the first to draw attention to the fact that the various foliated crystalline rocks usually classified as Laurentian were largely plutonic rocks, which have crystallized slowly, probably under an extremely gradual diminution of temperature, from a thickly viscid, coherent or tough hydrothermal magma. The foliation was explained as a result of 'differential pressure which by causing a yielding or deformation induced a flow in the mass.'

Previous, however, to the appearance of these results, the metamorphism of sedimentary rocks occurring 'as deeply buried and sunken strata' had been so clearly described and so strongly advocated by Lyell and others that their views gained an almost immediate and world-wide credence and adoption. It is, therefore, not surprising that, in the desire to trace back as far as possible the sequence of geological events as revealed by the accumulation of stratified deposits, there should have been included at the base a complex of crystalline rocks attesting the presence not of conditions favourable to sedimentation but revealing the early unstability of the necessarily thin and weak crust, as a consequence of which it was probably peculiarly subject to upwellings of the molten mass beneath. The ultimate result being a series of immense batholithic intrusions, composed for the most part of foliated plutonic rocks which subsequent upheaval and denudation have revealed at the present surface of the earth. The outward resemblance of these foliated or gneissic rocks to certain undoubted clastic rocks, present in later geological formations, which were known to have undergone extensive deformation and alteration, as well as their interfoliation with truly bedded rocks seemed abundant reasons for their classification as one uninterrupted series represented by this immense accumulation of stratified material. Their intimate association with crystalline limestones, which were believed to have originated in much the same manner as later calcareous strata, was also cited as additional evidence of their deposition as ordinary aqueous sediments. Subsequent work in the county of Argenteuil, rendered almost classic by the detailed labours of Sir William Logan, as well as in other extensive areas of Archæan rocks in Canada, have since shown the fallacy of many of the conclusions then reached, and both Adams and Ells are firmly convinced that the undoubtedly clastic rocks present in the area usually considered as 'typical' of the Laurentian, form but a small proportion of the rocky complex, while they are associated with and enclosed by much greater volumes of gneissic rocks closely allied in petrographical characters to granite, diorite and gabbro.

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‡Etudes synthétiques de géologie Expérimentelle, p. 432. Paris, 1879.

†Annual Report Geol. Surv. Can., vol. I., (N.S.), Part CC., 1885.

‖Geol. Mag., Nov., 1886.

*Bull. U.S. Geol. Surv., Nos. 28 and 62.

In the early years of the Canadian Geological Survey the advance of accurate and detailed information regarding these rocks was greatly retarded for several very obvious reasons. In the first place, by far the larger portion of the country characterized by the presence of such rocks was a vast almost uninhabited wilderness of forest. The only access to such regions was by means of canoes, through obstructed and often little known routes of travel. These conditions have in a great many instances been improved of late years by the gradual settlement of the country and the necessary construction of roads. In the second place great difficulty was for a long time experienced in obtaining trained and reliable observers competent to deal with the many difficult and complex problems presented. Sir William Logan, when carrying on his work in this connexion, was often forced to depend for information covering many essential details on observations by men scarcely possessed of the requisite qualifications.

Thirdly, the extreme metamorphism and deformation to which all such rocks had presumably been subjected on account of their very great antiquity, and the absence of any known methods by which their original minute structures and mineralogical composition could be deciphered, presented seemingly insuperable barriers to the complete and satisfactory explanation of their origin. In the fourth place the very natural assumption that such rocks represented extremely metamorphosed sediments, and the consequent application of the ordinary methods of geological research made use of in the much later and typical stratified deposits, served only to aggravate the difficulties already existing.

The adoption of the microscope for petrographical research removed the main difficulties attending a satisfactory study of these rocks, marking an era in geology, since which time the progress in exact knowledge has been rapid. In fact the accumulation of reliable information connected with this long-debated subject has already assumed such large proportions that many geologists look hopefully forward to the time when we shall probably possess an even more complete knowledge of these rocks and their manner of formation than we now do of many more recent rocks.

In 1844, when Logan decided to make an examination of the region bordering the Ottawa river, he found a mass of foliated crystalline rocks that seemed to him capable of subdivision into two conformable series, although in this, as well as many succeeding reports, he included them under the one group, which he subsequently called Lower Laurentian. The lower or older series consisted exclusively of 'syenitic gneiss showing no end to the diversity of arrangement in which the minerals and the colours will be observed, but there is a never failing constancy in respect to their parallelism. But this though never absent is sometimes obscure.' These rocks were supposed by Logan to occur in the form of a low anticlinal arch in the region extending from the Mattawa river to the vicinity of the combined mouths of the Montreal and Matabitchouan on Lake Timiskaming. The upper series is stated to crop out in the district to the south of the Mattawa and Ottawa rivers and to be characterized 'by the presence of important bands of limestone which have undergone extensive crystallization as a result of extreme metamorphism,' while the various gneissic rocks which separate the several bands of limestone 'differ in no way either in constituent quality or diversity of arrangement from the gneiss down.'

Subsequently, this lower gneiss was called the 'Ottawa Series,' while the upper group, differentiated solely in the first place on account of the presence of the limestones, was included under the name Middle Laurentian or Grenville Series. The name Upper Laurentian was given to a terrane formed chiefly of anorthosites which were afterwards shown to be of irruptive origin, and with which were classified by mistake certain gneissic and limestone bands, identical in character with those included as the Grenville Series and to which they clearly belong.

In the district, therefore, covered by the Nipissing and Timiskaming sheets, the rocks to be described would, under the old classification, have been included as Lower Laurentian, although in the area to the south of the Mattawa river precisely similar gneissic rocks, because of their inclusion of small isolated patches of crystalline limestone, have usually been described as of Grenville or Middle Laurentian age. These patches of crystalline limestone are only very occasionally present, and are evidently caught up by and embedded in much greater volumes of gneissic or foliated rocks here of truly igneous origin, in such a way as to point to the conclusion that in these limestones we may have small remaining portions of a sedimentary series, which, although highly altered, have not been wholly absorbed by the surrounding foliated material.

The term Laurentian, as applied in connexion with the map-sheets here under description, therefore includes only such granite and diorite gneisses as are usually characteristic of this ancient complex.

The gneissic rocks exposed throughout this district fall naturally into two great groups.

I. An acidic group:—consisting of those foliated rocks, similar in composition to granites, &c., to which they correspond, their differentiation being determined solely by their foliated texture, which, usually pronounced, is sometimes obscure and occasionally altogether absent.

II. A basic group:—These rocks occur interbanded with the more acidic gneisses, and represent either basic segregated portions of the granite magma or foliated basic irruptives allied to diorites, diabases, &c., caught up in it.

The results obtained from the detailed petrographical examination of the large number of thin sections prepared from typical specimens, specially selected as representing all the observed varieties occurring in the region, coupled with extended observations concerning their field relations, has furnished the most convincing proof that the vast majority of such rocks may be referred to some type of irruptive material. On the other hand those gneisses whose origin may be in doubt and which are in some cases held to be sedimentary constitute an exceedingly small proportion of the whole series. In fact, the results obtained from the examination and study are very closely analogous to the conclusions arrived at by Sir Archibald Geikie regarding similar old rocks exposed in the British isles, who says: 'These rocks are in the main various forms of eruptive material ranging from highly acidic to highly basic; they form in general a complex mass belonging to successive periods of extrusion; some of their coarse structures are probably due to a process of segregation in still fluid or mobile, probably molten, material consolidating below the surface; their granulated and schistose character and their folded and crumpled structures point to subsequent intense crushing and deformation; their apparent alteration with limestone and other rocks which are probably of sedimentary origin is deceptive, indicating no real continuity of formation, but pointing to the intrusive character of the gneiss.'

The chief facts which together seem to prove the originally igneous character of the rocks above referred to may be stated as follows:—

1. *Composition of the gneissic rocks.*—The microscope reveals at once the identity of these in mineralogical composition with the different known varieties of granite and diorite, the constituents present, in many cases, showing little or no alteration, except that produced by local weathering, or as a result of somewhat limited dynamic metamorphism.

In order to ascertain whether the chemical composition of these gneissic rocks would bear out the conclusions derived from their study in the field and under the microscope, six analyses were made in the Laboratory of the Survey by Mr. F. G. Wait. The following are the results:—*

—	I. Granitite-gneiss.	II. Granitite-gneiss.	III. Granitite-gneiss.	IV. Granite-gneiss.	V. Cyanite-granite-gneiss.	VI. Quartz-mica-diorite-gneiss.
Silica	71·69	69·39	67·74	67·50	66·94	44·92
Alumina	14·84	17·46	16·13	18·23	17·84	18·88
Ferric oxide	....	....	1·50	....	....	2·73
Ferrous oxide	1.25	1·38	1·96	2·39	4·30	13·76
Manganous oxide	tr.	....	tr.	....	tr.	0·26
Lime	1·63	2·14	4·41	1·85	1·86	9·07
Magnesia	0·37	0·52	1·36	1·56	1·82	5·38
Potassa	7·09	2·77	1·30	4·25	3·36	0·53
Soda	3·13	5·18	4·92	3·79	1·85	2·94
Water at 100° C	0·10	0·06	0·10	0·08	0·15	0·20
" above 100° C	0·49	0·47	0·86	0·90	1·75	1·62
Totals	99·99	99·37	100·28	100·55	99·87	100·29

I. Granitite-gneiss from west shore of Taggart bay, Kipawa lake—in previous reports usually referred to as red orthoclase gneiss, granitoid gneiss or gneissoid syenite. The rock is of a deep flesh-red colour, massive and granitic in appearance, the foliation being imparted by the parallel disposition of the coloured constituents. It is highly feldspathic and only very occasional thin bands of basic material occur which are at all continuous. It contains much microcline, orthoclase, plagioclase and quartz, with much smaller quantities of biotite and epidote. Sphene, sericite, chlorite, apatite, allanite and zircon are present as accidental or secondary minerals. The rock has evidently been subjected to considerable pressure. The feldspar and quartz have often undergone advanced granulation, while the surviving large individuals exhibit marked undulous extinction. Microcline, as might be expected, is abundant, as also areas of granophyre.

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*Annual Report, Geol. Surv. Can., vol. IX. (N.S.), Part R, pp. 18-20.

II. Granitite-gneiss from south shore of McLaren bay, Kipawa lake. This was selected as representing the light reddish-grey granitic gneisses so common in the district. The hand specimen shows a light-grey, rather fine-grained micaceous granitic rock, tinged with red oxide of iron, and showing only indistinct foliation; composed of orthoclase, microcline, plagioclase, quartz and biotite with a little apatite, zircon, sphene, magnetite and occasional minute individuals of secondary muscovite and epidote. The biotite shows a slight alteration to chlorite in some instances and occurs for the most part in small isolated plates, possessing a rude parallelism and rarely aggregated together. It shows only slight evidence of pressure.

III. Granitite-gneiss from west shore Lake Timiskaming at north end of Opimika narrows. A good average sample of the ordinary so-called grey-gneiss. Macroscopically this is a very distinctly foliated rock, the foliation being produced by alternating bands of light and dark-grey colours. The darker bands are composed almost wholly of the coloured constituents while the light-grey portions are made up chiefly of quartz and feldspar. The thin section shows quartz, orthoclase, plagioclase, biotite and epidote as the principal constituents. Epidote and titanite are common inclusions in the mica.

IV. Granite-gneiss from the northwest shore of Leonard inlet, Wicksteed lake. The hand specimen shows a rather coarse-grained, greyish, indistinctly foliated rock, much stained with yellowish-brown iron oxide and showing large phenocrysts of white orthoclase. The chief minerals present are orthoclase, microcline, plagioclase, quartz, biotite and muscovite. Apatite, zircon, epidote, zoisite, allanite? and pyrite were also noted in very small quantities. The rock has evidently been subjected to considerable dynamic action. The muscovite is primary, intergrown with perfectly fresh reddish-brown biotite.

V. Cyanite-granite-gneiss from the east shore of the Ottawa river, half a mile north of Snake creek. The hand specimen shows a coarse-grained granitic rock with a distinctly banded structure caused by layers rich in biotite, alternating with layers of quartz and feldspar comparatively free from that mineral. The distinctive feature of the rock is the abundance in portions of it of a light to deep-blue cyanite in large columnar individuals, some of which are half an inch across and an inch in length; garnets of a deep pink colour are also plentiful, and some individuals are as much as half an inch in diameter. Under the microscope the rock is seen to be composed of orthoclase, plagioclase, quartz, biotite, cyanite and garnet with smaller quantities of muscovite, graphite, titanite, zircon, apatite, pyrite, pyrrhotite and epidote. The rock is typically holocrystalline and granitic and shows no extreme evidence of granulation.

VI. Quartz-mica-diorite-gneiss from Ottertail creek, lower end of the second portage above the junction with the north branch. In the hand specimen this is a dark-grey, almost black, glistening, evenly foliated rock stained in places with iron oxide. It is composed of plagioclase, orthoclase, quartz, hornblende and biotite, with sphene, apatite, zircon, pyrite, magnetite and limonite as accessory minerals. The hornblende is much more abundant than the biotite. The evidence of pressure is very limited. The rock constitutes the dark basic bands so characteristic of exposures of the grey gneiss.

Time would not permit of the separate analysis of each rock-type included in the accompanying table, and therefore no attempt can be made to institute comparisons in detail with the published analyses of granites and diorites. Sufficient has been done, however, to show somewhat clearly that in general these foliated rocks bear a close analogy in chemical composition to their massive equivalents, while on the other hand they are quite different in this respect from any rock resulting from ordinary processes of sedimentation. As Dr. Adams remarks,* the points of distinction and those which mark them as of igneous origin are, high silica, combined with low alumina and high percentage of alkalies. The lime also, as is usually the case in granites, is in excess of the magnesia. It would seem, however, that the granite-gneisses, as a rule, are more basic than their massive equivalents, although presenting an equally wide range in their silica contents. The decrease in silica is accompanied by an increase in the alumina, while soda tends to exceed potash in the more basic varieties, thus marking a passage to the gabbros and diorites. The high percentage of alumina with low alkalies noticed in No. V. is due to the presence of cyanite, but otherwise the composition is essentially similar in every other respect to the ordinary granitites of this and other Archæan districts. There is, as is usual in granites, the preponderance of lime over magnesia, which though slight in this case is nevertheless in marked contrast to the sillimanite gneisses described by Adams* where the magnesia is often nearly three times as abundant as the lime.

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*Annual Report, Geol. Surv. Can., vol. VIII. (N.S.), Part J, p. 44.

The quartz-mica-diorite (VI.) is analogous in chemical composition to the most basic phases of the gabbros and diorites. The hornblende and biotite are much more abundant than the feldspathic constituents, while quartz is only very sparingly represented.

2. *Microscopical structure.*—The various thin sections examined show unmistakeably the holocrystalline structure so characteristic of granite, diorite and gabbro, the feldspar and quartz individuals forming comparatively large areas of interlocking grains, especially in the more acidic portions or bands in the rock, with which are associated the hypidiomorphically bisilicate constituents. There is no suggestion whatever in the great majority of such rocks of the scondary enlargement which in certain arkoses and quartzites produces a somewhat similar interlocking arrangement, as the rocks have, in many instances, been subjected to but limited metamorphic action. The foliation, which is the differentiating characteristic of these rocks, is often so coarse that it is only apparent in large specimens or somewhat extended exposures of the rock. This parallelism is, therefore, often indistinguishable with the microscope, so that in the thin sections the resemblance is complete between foliated and non-foliated varieties of such essentially similar mineral aggregates.

At the present day fused magmas are regarded as more or less complex solutions, which, by reason of their high temperatures, obey the same laws in the order and method of their solidification as those which govern the crystallization of ordinary solutions of a similar heterogeneous composition. Thus, in the numerous thin sections examined, a certain general and definite order is observable in the generation or crystallization of the various component minerals, that has been rather closely adhered to in the progress of consolidation. In this manner zircon, sphene, apatite and primary epidote, which are the first to form in the slowly cooling mass, are almost invariably present in sharply outlined and well developed crystals, evidencing considerable freedom from restraint during the progress of their formation. The various iron ores which may happen to be present are of earlier generation than the coloured or bisilicate individuals, which latter are usually present with hypidiomorphic outline, although occasional individuals often show sharp and well defined crystallographic boundaries. The customary grouping together in masses or nests of such basic material produces a mutual interference of the constituent individuals which militates greatly against perfection of crystal boundaries. The various apatites, sphenes, &c., which are the first minerals to form in the cooling rock-mass, usually occur, as might be expected, either embedded in, or in close conjunction with such ferro-magnesian constituents, although the rest of the rock, while much poorer relatively in such minerals, may not be entirely free from them. The feldspar and quartz, which are the last to solidify, occur in more or less irregular areas, usually elongated in the direction of the foliation, or showing, especially in the case of the quartz, that the residual spaces existent in the rock-mass were already of this form and character.

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* Annual Report, Geol. Surv. Can., vol. VIII. (N.S.), Part J, p. 44.

3. *Macroscopical structure.*—The various dark and light-coloured bands of relatively greater or less basicity succeed one another across the strike or cut one another off, thus suggesting even to a casual observer a complicated intrusion of one portion through another, although the frequent absence of any distinctly recognizable boundary between the different folia shows clearly that such conditions obtained in the mass long before its final consolidation. Although, especially when arranged in approximately horizontal position, the alternation of such bands resembles somewhat closely the parallelism produced by the alternating sequence of stratified material of differing coarseness and composition, a closer inspection shows that there is no evidence whatever of the sorting and re-arrangement by aqueous agencies so characteristic of all sedimentary strata. The tendency to nuclear aggregation observed in the crystallization of the first-formed constituents seems to be a usual and marked feature, not only of slow cooling magmas, but of all highly saturated and complex solutions when undergoing change to the solid state. It is, therefore, quite evident, both from macroscopic and microscopic examination, that perfection of foliation is reached in these gneisses when during the process of cooling accompanied by differential movements the pressures produce a kind of flow in the still mobile mass, thus tending to the parallel disposition of the various bands or masses of differing composition. The viscosity of the whole was such as to prevent the too free transmission of the material of contiguous bands or portions, thus furnishing the approximately sharp lines of division so frequently observed.

4. *Junction with overlying rocks.*—The immediate contact, or line of junction, with originally overlying clastic rocks, reveals undoubted evidence of the irruptive character of the gneisses. Numerous and detailed observations have been made of the line of demarcation between these Laurentian gneisses and Huronian slates and quartz-

ites, which latter are of undoubted clastic origin. The behaviour of the gneissic rocks under these circumstances is precisely similar in every respect to that which obtains in the case of granite, intrusive through neighbouring bedded strata. Detailed descriptions have already appeared* regarding the various contact phenomena witnessed along the line of junction between the Laurentian and Huronian, embracing not only this region, but also the district to the southwest included within the area of the Sudbury and French River map-sheets (Nos. 130 and 125, Ontario). The facts there noted, and since borne out by more extended observations, show distinctly that the gneisses are intrusive in the Huronian, and are, therefore, in their present form younger than the clastics which they invade. Although, in places, a seeming transition exists which might be mistaken for an alternating sequence of stratified material, the relations thus observed find their true explanation in the presence, at these places, of a zone of varying thickness formed by a commingling of the sedimentary material with the igneous rocks, as a result of actual fusion, or by the presence of a series of more or less parallel dikes piercing these clastics.

The foliation presented by these rocks is of two distinct kinds, although there is almost every possible graduation between these two extremes. It may consist of the parallel arrangement of certain of the constituent minerals, usually the bisilicates, but sometimes also the porphyritic feldspars, or it may be due to an alteration of lighter or darker bands, showing a varying chemical and mineralogical composition. Intermediate phases of such structures are produced by the development, in more or less approximately parallel position of nuclei, or nests, of the ferro-magnesian constituents, whose gradual coalescence into ever-lengthening bands produces ultimately that perfection of foliation actually found.

The foliation just described is the one characteristic of the more massive and granitoid varieties, included under the first or acidic group, and is evidently the result of the application of pressure to a magma of somewhat homogeneous composition. On the other hand, the second variety of foliation is produced by alternating sequences of rocks belonging to both acidic and basic groups, and has been imparted to the rock-mass as a result of differentiation in a slowly cooling magma of heterogeneous composition, aided by a flowing movement in a more or less constant direction.

The results obtained by the microscopic examination indicate, in the most positive manner, that the banded structure so universally observable in such rocks was imparted to the whole mass while still in a molten, or, at most, only partially consolidated condition. One of the most significant facts noticed in this connexion is that many of the most markedly foliated gneisses show little or no trace of having been subjected to any great degree of deformation; nor is there any reason whatever to suppose that the rocks so examined have undergone such recrystallization as to mask the evidence of such action, if any previously occurred. In many instances it is equally certain that subsequent dynamic action has, after the complete solidification of the magma, somewhat modified and accentuated such foliation, but even in these cases there is every reason to believe that pronounced parallelism previously existed as a primary structure of such rock-masses before the application of pressure.

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*American Geologist, vol. VI., pp. 19-32 (July, 1890), also Bull. Geol. Soc. Am., vol. IV., pp. 313-332.

The somewhat uniform direction in strike of this banded structure over the larger portion of the area covered by the accompanying map-sheets, and its marked correspondence in direction with the line of outcrop of the neighbouring stratified Huronian rocks, seems to point to the conclusion that the resistance offered during the irruption of these gneisses by such hard strata has been the main determining feature of the direction of foliation. During the progress of this igneous invasion the forces of upheaval acted along certain definite lines or centres, thus producing irregular ovoid forms, often of great area, the inner portions of which are now occupied by comparatively flat-lying gneisses, or, in occasional instances, by more massive or granitoid varieties, surrounded by an outer border or zone where the foliation becomes much more pronounced. In certain instances, where the dome-like structures thus produced have been denuded and are of limited extent, a great diversity exists in both the direction and angle of dip of the foliation within a comparatively small area, but where, as is usual throughout this district, these ovoid areas are of great size, the direction of foliation shows a corresponding increase in uniformity.

Intimately associated with these gneisses and granites are certain portions, often of themselves constituting considerable and therefore important rock-masses, which, on account of certain peculiarities of composition, as well as from their structural relations with the surrounding rocks, have been commonly referred to as 'pegmatite,' and which by reason of their usually coarse crystallization have been sometimes called 'giant granite.' Haüy first applied the name pegmatite to the intimate admixture of orthoclase and quartz, also known as graphic granite. Later, Naumann extended its use to include all the coarse varieties of muscovite-granite, vein-like in appearance and frequently containing tourmaline. Subsequent writers, as detailed investigations into its composition and origin proceeded, have still further widened its use, until, at the present day, the employment of the term in connexion with that of the parent plutonic mass with which it is associated is necessary before any definite idea can be formed of its precise mineralogical composition. In petrography the terms micro- and macro-pegmatite have always been used in a structural sense only to denote those intergrowths of quartz and feldspar, or of two differing species of feldspar which are sometimes characteristic of occurrences in rocks of these minerals. Thus the various plutonic masses of syenite, diorite, gabbro and diabase may each have their individual pegmatitic equivalents, representing the final product of their solidification, although the abundance of such aggregates in connexion with these rocks is much less than in the case of granites. This comparative infrequency is perhaps most adequately explained by the relatively much greater basicity of uch rocks, their more rapid rate of cooling, as well as the comparative scarcity, throughout the greater portion of the mass, of any such abundant and intimate association of fused rock and heated water as would tend to their formation; for, while it has been clearly shown by M. Fouqué and Michel-Lévy, that diabase and similar basic rocks may be artificially reproduced in the laboratory from a state of simple dry fusion, it is extremely doubtful whether any extensive intrusive process produced by natural causes is ever unaccompanied by a greater or less abundance of superheated water as an integral portion of the fused mass.

In the region under description the granite pegmatites are, as usual, by far the most abundant, but there are occasional dikes in which the occurrence of oligoclase and hornblende as the main constituents would determine their classification with the diorites.

In composition these pegmatite masses consist essentially of quartz and the more acid feldspars, chiefly orthoclase, oligoclase, albite and microcline, while muscovite is the prevalent ferro-magnesian constituent, when any is present, and hornblende and biotite are much less characteristic. The parallel intergrowth of orthoclase and albite, to which the name perthite has been applied, is an abundant and sometimes prevailing feldspathic constituent of the pegmatite dikes, especially in the vicinity of Mattawa. The composition is, therefore, somewhat variable, but these dikes or vein-like masses are essentially similar, though somewhat more acid than the normal plutonic rock of which they represent the most highly differentiated or final product of consolidation. Thus, in those areas where the gneissic rocks contain a superabundance of basic material, with plagioclase as the predominating feldspathic constituent, the associated pegmatite usually shows a corresponding increase in relative basicity, oligoclase seemingly being the most abundant feldspar. In areas of hornblende-granite the associated pegmatites contain hornblende as the coloured constituent. The preponderance of the granitite gneisses, or biotite-granite-gneisses in this region, is represented also by a far greater relative abundance of the pegmatitic phases of such rocks, while the far greater prevalence of muscovite, which usually occurs altogether replacing the biotite of the normal parent plutonic, evidences the presence of the greater abundance of heated water tending to the more or less complete elimination of the iron present in this bisilicate and the consequent conversion of the mineral into muscovite.

The pegmatites have not yet been examined sufficiently in detail to call for any lengthy mention of their accessory or accidental minerals. In other districts these masses are especially noted as favouring the development of many of the more unusual and rare minerals. In a pegmatite dike cutting gneissic rocks about a mile northwest of Eau Claire station opaque crystals of beryl occur. The crystals secured are usually of a pale yellowish, but sometimes of a bluish, colour and some of them would exceed five pounds in weight. An examination by Mr. R. A. A. Johnston* of some specimens collected from the same locality by Mr. W. C. Willimott showed likewise the presence of the comparatively rare minerals, xenotime and polycrase. Cyanite, although an abundant constituent of the granitite-gneisses in the vicinity of Les Erables rapids and the mouth of Snake creek on the Ottawa, exhibits its most perfect crystallographic development in the coarser and more acid bands which are evidently of pegmatitic origin. Fluorite is also an abundant and frequent constituent in the pegmatites cutting the gneisses near the Ottawa in the township of Cameron, about five miles east of Mattawa. In the necessarily more or less hurried examination of the large number of these pegmatite masses there was found, however, a conspicuous monotony in composition.

The intrusive character of pegmatite is now so generally recognized that the various theories, formerly extant, regarding it as in some manner due to aqueous infiltration and deposition, may be considered as disproved, while the view that pegmatite constitutes the most acid phase or final differentiation product attending the progressive crystallization of certain intrusive plutonic rocks has been very clearly and ably set forth by Lehmann,[*] Brögger[†], Williams[‡] and others, and all have given expression to the opinion that water played a most important role in their formation. Probably the most satisfactory explanation which has yet appeared is that lately issued as the joint production of Messrs. W. O. Crosby and M. L. Fuller of Boston.[§] These authors recognize "that the most satisfactory explanation of this blending of the pegmatite with quartz veins on the one hand, as with the normal granite on the other, is to be found in a corresponding blending of aqueo-igneous fusion with igneo-aqueous solution; and this dynamic gradation, it appears to us, can only result from the gradual hydration of the residual magma during the slow centripetal solidification of a body of magma and a consequent elimination of water."

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*Annual Report, Geol. Surv. Can., vol IX, (N.S.), p. 13 R ; also Am. Jour. Sc., March, 1899, p. 243 ; also Summary Report Geol. Surv. Can., 1898, p. 167.

In this paper the authors further state that pegmatite should be regarded, 'not as a distinct species or family of rocks, but rather as a possible textural phase of all, or nearly all, the plutonic rocks; and we may, in general, say of any plutonic rock that it may be cryptocrystalline, micro-crystalline, macro-crystalline or pegmatitic.'

The consensus, therefore, of recent opinion, seems to favour an intrusive origin for pegmatite, the progressive increase in hydration of the residual magma being explanatory by a corresponding increase in acidity of its later crystallization.

The stages represented completely by the occurrences in this region show a perfect and practically uninterrupted continuity during the consolidation of these rocks, from an original condition of hydro-igneous fusion characteristic of the magma from which the comparatively fine and even-grained parent plutonic is generally believed to have resulted, to conditions of aqueous solution which must have obtained in the viscous mass from which the latest quartzose segregations have solidified. Such views are in harmony with the known occurrences of most of the quartzose masses and veins so frequently present in these Archæan rocks, and which have evidently originated by a process closely allied to that described above, in consequence of the deposition from supersaturated solutions of highly siliceous material, and are substantially contemporaneous with the parent plutonic mass with which they are so intimately associated.

The age relations of the component minerals are practically the same as that in the more usual types of plutonic rocks. Thus biotite, muscovite, and the more basic feldspars crystallized out in regular succession in the order mentioned, showing a gradual decrease in perfection of idiomorphic development. The more acid feldspars, and finally the quartz, follow, the latter especially showing little or no evidence of crystal boundaries occupying the interspaces left by the earlier development of the more basic constituents. When drusy cavities exist in these pegmatites, as well as in the quartzose and more vein-like occurrences, the silica sometimes exhibits a decided tendency towards crystalline development. The presence of such unfilled spaces, especially in the immediate vicinity of such perfect crystal forms, seems to furnish evidence of the insufficiency of the siliceous material in solution to fill the spaces, permitting a more or less unrestricted development of the remaining quartz. They likewise point, not only to the extreme acidity of the last remaining portion of the partially solidified magma, but also to its approximately homogeneous composition.

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[*] Ueber die Entsehung der altkrystallinischen Schiefergesteine Augit und et seq.

[†] Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit und Nephelinsyenit I, Theil pp. 215-225. Translated by N. N. Evans, Can. Rec. Sc., vol. VI., Nos. 2 and 3, pp. 33-46 and 61-71.

[‡] Origin of the Maryland Pegmatites, XVth Ann. Rep. U.S. Geol. Survey, pp. 675-686.

[§] Technology Quarterly, vol. IX., No. 4, December, 1896, pp. 326-356.

The exact depth below the earth's surface necessary for the formation of these pegmatites and their parent masses of normal plutonic rocks, as well as the amount of pressure during the progress of their crystallization, is a mere matter of speculation. Of recent years a perfect gradation has been traced from the typical holocrystalline structure characteristic of granite, gabbro and other plutonic rocks, in a vertical distance of a few hundred feet upward, into a porphyritic phase at the surface; while the pressure required, as pointed out by Brögger, would be obtained by the presence of superimposed material, great enough to prevent the water separated out by the progressive crystallization from escaping freely to the surface.

The most distinctive feature concerning the development of these masses is their extremely coarse crystalline texture, which is in very striking contrast to the normal or usual crystallization of the parent plutonic rock with which they are associated. The resemblance in many of the quartzose varieties to quartz veins, originally regarded as due solely to lateral secretion and aqueous deposition, is so very marked that it is difficult to see how any hard and fast line can be drawn between these separate occurrences. Usually in these cases there is a somewhat indistinct zone-like arrangement of the material, the masses presenting a finer grained feldspathic portion in the vicinity of the walls, and showing a continuous transition towards the interior, which is often occupied by comparatively large allotriomorphic masses of almost pure quartz. Usually there is a perfect gradation into the parent plutonic when this is the enclosing rock-mass, while an undoubted passage can very frequently be traced into areas of pure quartz, and occasionally into rather typical or ordinary quartz veins.

In the region embraced by this report there are two somewhat distinct phases of such rocks. The most frequent and abundant is perhaps represented by the acidic facies of the gneisses constituting the coarser and more feldspathic and quartzose bands. These present all the distinguishing characteristics of pegmatite, although occurring in perfect conformity with the prevailing foliation. In composition they show the usual great preponderance of feldspar and quartz, with only very occasional flakes of biotite, which in many cases has undergone notable bleaching owing to the elimination of a considerable proportion of the iron originally present. Such biotite is much paler in colour, with less marked pleochroism, and shows the brilliant chromatic polarization colours, though perhaps in a less degree, so characteristic of the lighter coloured mica. The most frequent and abundant coloured constituent, however, is muscovite, which in some cases, at least, is an original constituent, although a great deal has undoubtedly resulted from the alteration of the biotite. These pegmatitic bands very evidently represent the residual and more acid portions of the magma which have crystallized *in situ,* and may be referred to as examples of what has been called 'sedentary pegmatite.' They usually show a perfect, though somewhat rapid, transition into the more basic bands immediately adjoining, and are, therefore, to be regarded as more strictly contemporaneous than those constituting the second mode of occurrence. These are masses or apophyses of residual and consequently more fully hydrated and acid portions of the magma, which have invaded and filled various cracks and fissures occurring in the gneissic *massif* or in the neighbouring clastic rocks. They are usually present in more or less marked conformity with the foliation of the gneissic rocks, but very often fill rifts which intersect this at considerable angles. Although in the detail of their structural relations many of these occurrences are obviously newer than the associated gneisses, the general examination of the masses throughout the whole area seems to show that they must be regarded as substantially of the same age. The process of crystallization was evidently practically continuous from the first development of the earlier constituents in the still molten and viscous magma to the filling in of the most minute cracks and fissures by the remaining quartz, marking the final step in the complete solidification of the whole mass. Intimately associated genetically with these pegmatites are certain veins and even veinlets of quartz, sometimes containing feldspar, which penetrate and anastamose through the prevailing gneisses as well as through the clastic rocks of this district. These are especially numerous and well developed along the lines of contact between the various plutonic masses and the Huronian clastics, and it seems probable that by far the greater number of these infiltrations of secondary quartz are due to the extravasation and differentiation of the numerous large masses of these deep-seated irruptives exposed so frequently throughout this area.

In those portions of the area coloured as Laurentian, where the rocks present have solidified from a magma more or less homogeneous in composition, the foliation generally present is seen to consist usually of a parallel alignment of the bisilicate individuals, or, at most, of small nests or nuclei composed of an aggregate of scales or fragments of such constituents. Such rocks are in many instances of somewhat later generation than the more evenly foliated gneisses, and frequently contain considerable masses or fragments of these that have been caught up during the irruption of the former. At other times such homogeneous masses are simply more granitoid portions of the prevailing gneiss, into which they merge both across and along the strike of the foliation, so that both are strictly contemporaneous with one another. The area of granite to the northeast of Lake Timagami, especially in the vicinity of Carrying and Annima-Nipissing lakes, has a marked foliated texture, due to the more or less parallel disposition of aggregates of greenish chlorite scales resulting from the decomposition of the biotite originally present. This foliation is more pronounced near the junction with the Huronian slates on these lakes, gradually fading on passing inwards towards the centre of the mass. On Lake Timiskaming, as well as near the south end of Cross lake, the Laurentian in contact with the breccia-conglomerate of the Huronian is a massive granite, very poor in bisilicates, but which gradually merges southward into very typical and evenly foliated gneiss, showing the usual alternating sequence of acidic and basic material. In the vicinity of Lake Nasbonsing the rock, wherever exposed, is a massive flesh-coloured gneiss very rich in orthoclase and microcline, while the foliation is produced by the parallel disposition of a rather sparing quantity of hornblende and garnet. This rock passes by insensible gradations into the more evenly foliated varieties exposed on the north shore of the lake between Nasbonsing and Bonfield stations, although in the vicinity of Bonfield station itself the rock is so massive that little or no structural details could be traced.

Where greater heterogeneity in the original composition of the magma has prevailed the foliation present shows a corresponding increase in the perfection of its development, consisting as it does of alternating bands of lighter and darker coloured material, representing numerous varietal forms of rock-types which may be referred respectively to either the acidic or basic groups already mentioned. This foliation it is which generally characterizes the rocks exposed in the area covered by the accompanying map-sheets.

The component bands are of variable thickness. Occasionally there is an exceedingly sharp line of demarcation between the alternating folia, but as a general rule there is a complete though somewhat rapid transition from one to the other. Even in their subordinate arrangement the constituent bands show the same marked tendency towards parallel arrangement, and a thick bed of prevailing feldspathic composition will, in cross section, present short dashes or small patches of biotite or hornblende all drawn out in one direction; while, on the other hand, the more basic portions show a similar definite arrangement of long lenticules of lighter coloured material, in which a relatively greater amount of feldspar or quartz is present. The continuity of these folia, both large and small, is broken at frequent intervals, sometimes abruptly, but usually by a gradual thinning out in either direction. Frequently, before such interruption takes place, bands of essentially similar composition may be formed immediately above or below, which in turn pinch out in both directions to be again replaced by others. This irregularity in horizontal arrangement is equally true of their downward or vertical extension, so that the whole section of even a small area of any such rock-exposures presents an exceedingly complicated arrangement of lighter and darker material of greatly varying acidity and basicity. It is quite evident from their macroscopic arrangement that their formation was attended with an extremely gradual diminution of temperature, for the frequent absence of sharp lines of demarcation between these bands of widely different composition seems to point to the re-absorption by the later and more acid portions of the magma of the first formed or faster cooling basic portions, perhaps many times repeated before the final consolidation of the whole mass.

In many places the dark bands evidence the action of extensive crushing and crumpling, showing that great movements have taken place in the whole series. These movements were doubtless approximately synchronous, and closely connected with the invasion and cooling of the more acid portions of the magma. The most curious and complicated structures are thus often produced, this complexity being enhanced by the frequent dislocation, accompanied sometimes by considerable separation and displacement, of those portions which evidently existed originally in unbroken continuity. Such intricate structures are, however, usually extremely local in their development, the gneiss elsewhere in the vicinity often showing little or no sign of extreme disturbance. Although, as a general rule, the direction of this foliation shows a marked uniformity over large areas, there is a considerable diversity in arrangement in this regard, as indicated on the accompanying maps.

A careful correlation of the many observations made shows clearly that these gneissic rocks occur for the most part in the form of large rudely oval or concentric masses whose longer axes have in general a direction according with the prevailing strike of the foliation. Frequently such large ovoid masses present quaquaversal dips, which in cross-section simulate the ordinary anticlinal arch. About a mile east of Mattawa station the Canadian Pacific railway cuts through a small dome of these gneissic rocks, composed of beautifully sharp alternating feldspathic, micaceous and quartzose bands, showing a remarkably perfect example of very pronounced differentiation. The section as presented on either side of the railway track presents a marked resemblance to a low anticlinal dome. Plate III. The truly igneous character of the composing rocks, however, would not permit of such an interpretation. In size these ovoid masses vary greatly, some of the curvings belonging to ellipsoids many miles in diameter, while others are a mile or less in diameter.

As a rule the folia or *laminæ* have a prevailing dip to the southeast or south, which is singularly uniform over large areas. This inclination is generally rather steep, usually considerably over 45°, while, frequently, as in many places along the shores of Lake Timiskaming, the foliation is almost, if not quite, vertical. On Seven League lake and southwards to Mattawa, as well as westwards to Tomiko lake, the bands frequently succeed one another in almost horizontal succession, the dip, if any, being generally southwards at a low angle. Even in this area, however, there are frequent exceptions to this rule, and the rocks often show a rapid change in this prevailing horizontality as though the bands had been subjected to frequent disturbances and dislocation during the progress of their formation. Thus in the vicinity of North Bay and the northern portion of Lake Nipissing the gneisses often approach a vertical attitude, while on the southern shores in the vicinity of French river similar rocks are nearly horizontal.

PETROGRAPHY OF THE LAURENTIAN.

The petrographical work done in connexion with the present report was carried out with the co-operation of Mr. W. F. Ferrier, Lithologist to the Geological Survey, to whom credit must be given for many of the results obtained.

The writer and Mr. Ferrier worked in conjunction on the problems involved and with so free an interchange of ideas throughout that no attempt will be here made to separate the examinations, more than to mention that many of the more critical specimens were made the subject of special study by Mr. Ferrier.

The main object of these detailed studies has been not only to obtain more accurate information with regard to the composition and minute structures of the various rocks, but also to gain an increased knowledge of their origin and the relationship existing between the alternating bands of relatively greater or less basicity.

Incidentally a table has been prepared, showing a classification of these old crystalline rocks, displaying not only their composition, but also their close affiliation with one another. This table may recommend itself to petrographers, as it has done to the authors, and it is hoped may be found of material use in future work undertaken in areas of similar Archæan gneissic rocks.

Much microscopical work has been accomplished in connexion with a series of specimens taken as illustrative of the various contact phenomena exhibited along the line of junction between the Laurentian and Huronian. This has enabled a more accurate interpretation and description of the various facts having reference to the relative ages of these two series of rocks. Field-work, no matter how careful or extended, in areas characterized by the presence of Archæan strata, must of necessity lose much of its value if unaccompanied by concurrent petrographical studies. In the present instance the results have been adduced not only from a critical and extensive examination of the numerous rock-exposures in the field, but also by a careful correlation of the facts thus ascertained with those acquired in the petrographical laboratory.

Classification.

Any system of classification applied to such a series of foliated rocks must, necessarily, in some respects be unsatisfactory; but a grouping together according to their mineralogical composition seems on the whole to be the best that can be adopted in the present state of our knowledge.

As already stated, however, there can be no doubt that all of the petrographical types represented in the gneisses from this region are allied in their chemical composition and mineral constituents to such plutonic igneous rocks as granite syenite, diorite gabbro, etc., but, as might be expected, there is a passage from one rock-type to another, sometimes gradual, sometimes very abrupt, according to the abundance or scarcity of certain minerals.

It must be borne in mind that the classification here adopted is an arbitrary one, based on the mineralogical composition of the rocks, and to a certain extent on variations in their structure, the object being, excluding theoretical considerations, to establish certain well defined petrographical types that have been found to be constant in the area examined, and to which specimens from other districts may be referred.

No attempt has been made to examine minutely all the specimens collected, but good examples of the more prevalent types have been selected and described in detail.

As previously stated the gneisses of the region may be placed in two great divisions, the acidic characterized by orthoclase as the predominant feldspar, and the basic by the predominance of plagioclase. Biotite is by far the most abundant ferro-magnesian constituent of the first division, and hornblende of the second.

The first division may be subdivided into seven groups, dependent on the presence of one or other of the coloured constituents. Arranged, approximately, according to frequency of occurrence in the collection, they are as follows:—

1. Gneisses characterized by the presence of biotite and primary epidote.
2. Gneisses in which biotite alone is present.
3. Gneisses in which both biotite and muscovite occur.
4. Gneisses in which hornblende accompanies the micas.
5. Gneisses in which cyanite, graphite, garnet, etc., accompany the biotite.
6. Gneisses in which hornblende alone is present.
7. Gneisses in which muscovite alone is present.

The relationship of these rocks to their analogous massive types may be seen by reference to the accompanying table.

Of the second division, the basic or hornblende gneisses, two varieties may sometimes be distinguished, first, those which represent seggregated bands of the more basic material of the original granitic magma, and secondly, those which are undoubted basic eruptives folded-in with the more acidic gneisses.

It is not always possible to make this distinction, but examples of each of these two varieties have been observed.

Classified according to their mineralogical composition they naturally must be placed close to each other.

Amongst the first, whilst certain names have been applied to individual specimens, it is manifest that no hard and fast lines can be drawn in the field. For instance, a band of which one portion would have the mineralogical composition and characters of a quartz-mica-diorite may pass insensibly into material having all the characters of a hornblende-granitite, according as the plagioclase diminished and monoclinic feldspar increased in quantity.

One remarkable fact in connexion with these basic bands is the great scarcity in them of augite, none of the hornblende containing cores of that mineral, or affording any direct evidence of having originated from it.

In the Laurentian area lying to the north of the Island of Montreal, recently described by Dr. Adams,* on the contrary, the basic bands in the gneiss appear to consist largely of pyroxene rocks.

I.—The Granite-gneisses.

In colour these rocks range from a light-grey to a decided red. The red rocks represent what has usually been called by the older writers on the Archæan, the 'red orthoclase gneiss,' but we find in the field every gradation from the grey to the red gneiss, the one passing imperceptibly into the other in many localities, and the microscopical examination has failed to detect any essential point of difference between these two varieties.

The red gneisses contain a large quantity of hydrous iron-oxides distributed through them, to which the coloration is due, and they also appear to have a larger proportion of microcline than the grey ones. Plagioclase was not observed to exist in any greater quantity in the grey varieties than in the red ones.

Many of the more altered mica-gneisses have assumed a dark-green colour, owing to the chloritization of the biotite, but microscopic examination shows that they may be included in the same class as the typical unaltered ones.

These chloritized mica-gneisses have been frequently, though erroneously, spoken of as hornblende-gneisses by the earlier geological observers in this region, who were misled by their colour and had not the advantages afforded by microscopical examination of the rocks. A remarkable feature of these gneisses is their comparative freedom from iron ores.

When pyrite occurs it is almost always associated with large clove-brown sphenes.

In the case of the micaceous gneisses, *i.e.*, those in which biotite alone, or biotite and muscovite together, constitute the predominating ferro-magnesian constituents, hornblende was observed in only two instances, and then in minute quantities.

The almost total absence of augite from these rocks is to be particularly noted. Even in the basic hornblende-gneisses of the region this mineral is very rarely, if ever, to be found.

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*Annual Report, Geol. Surv. Can., vol. VIII. (N.S.), Part J., 1896.

A. *Biotite-muscovite gneisses—(Granite-gneiss)*.—The rocks grouped together under this heading are, like the other gneisses, holocrystalline and granitic in their structure. Both biotite and muscovite are present as the chief, and in fact almost the only, coloured constituents. These two micas occur intergrown with each other in aggregates of broad fresh plates. The specimens representing this rock-type are, apparently, not very numerous in the collection. Those examined are remarkably free from epidote, iron ore and titanite.

Orthoclase and microcline are the predominating feldspars, and granophyric intergrowth of the quartz and feldspar is a common feature.

B. *Muscovite-granite-gneiss—(Pegmatite in part)*.—The rocks thus designated and classified are of comparatively rare occurrence as strictly integral portions of the gneissic complex, and where present constitute the latest secretions from the original magma.

In reality they represent interfoliated bands of pegmatite, although of much finer texture than the rock to which that name is usually applied. In colour they are white, light-grey, or pale-pink, presenting glistening or pearly cleavage planes. Under the microscope they present the usual interlocking holocrystalline aggregate of quartz, orthoclase, plagioclase (oligoclase) and microcline, with a smaller amount of sericite (hydrous muscovite) arranged in long drawnout scales and plates which traverse the rock in curving and approximately parallel bands. A small quantity of epidote and zoisite in crystals and grains, some of which may be primary, is associated with small scales of sericite, the latter, at least, being one of the products of the incipient decomposition of the feldspathic constituents. Occasional small flakes or scales of a much bleached biotite occur, some of which form a parallel intergrowth with the muscovite. The specimens examined have undergone extensive deformation, as a result of pressure subsequent to the cooling of the rock, and both feldspar and quartz have suffered a somewhat marked granulation, while the surviving individuals of both these minerals exhibit wavy extinction rather perfectly. Some of the muscovite is doubtless of primary formation, although some has evidently resulted from the shearing of the feldspar.

C. *Biotite-granite-gneisses—(Granitite-gneisses)*. Var. (*a*) Biotite-epidote-gneiss.—The combination of biotite and epidote as the principal coloured constituents forms a well defined rock-type which has been found to be remarkably constant over large and widely separated areas, and is the one which is represented by the largest number of spcimens.

These rocks are undoubtedly of irruptive origin, and are, in fact, foliated granitites, thoroughly holocrystalline and granitoid, varying from coarsely to finely crystalline; the constituent minerals being, as a rule, equally developed on all sides.

Var. (*b*) Biotite-gneiss. These are foliated, holocrystalline, granitic rocks in which biotite alone, or accompanied by very trifling quantities of secondary epidote, is the ferro-magnesian constituent.

In the specimens of this type of rock which have been examined the mineral does not occur, as a general rule, in aggregates of broad plates, but in isolated independent ones which have an approximately parallel arrangement determining the foliation of the mass.

Var. (*c*) Biotite-cyanite-gneiss. This gneiss, though somewhat remarkable in its mineral composition, in that it contains cyanite, garnet and graphite in addition to the biotite which chiefly characterizes it, does not present any evidence whatever, either in its microscopical structure or its field relations, of any other than an irruptive origin.

It is a perfectly fresh, holocrystalline, foliated granitic rock, and possesses in its structure no features which would at all suggest recrystallization. It seems to be a peculiar local phase of the prevalent biotite-gneisses of the region, differing in no way from them as regards origin.

A somewhat similar gneiss from near Wanapitei station in the Sudbury district has recently been petrographically described by Dr. T. L. Walker,* who, however, says little regarding its microscopical character and field relations, beyond assigning it to the Laurentian and stating that he regards it as a 'true gneiss' and not a crushed granite.

Var. (*d*) Hornblende-granitite-gneiss.—The rock thus classified differs but little in microscopical character from the ordinary micaceous form of the granitites, although usually darker in colour and more basic in appearance. It shows a transition on the one hand into granitite containing biotite alone as the coloured constituent, which is the prevailing type of these gneissic rocks, and on the other into hornblende-granite-gneiss, which latter facies is of rather rare occurrence throughout the district. In all previous descriptions the hornblende-granite-gneiss has been reported as the variety most commonly present in the Laurentian, the mistake having undoubtedly arisen from the frequent chloritization of the biotite originally present in

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*Geological and Petographical Studies of the Sudbury Nickel district. Quart. Journ. Geol. Soc., vol. LIII., p. 42, 1897.

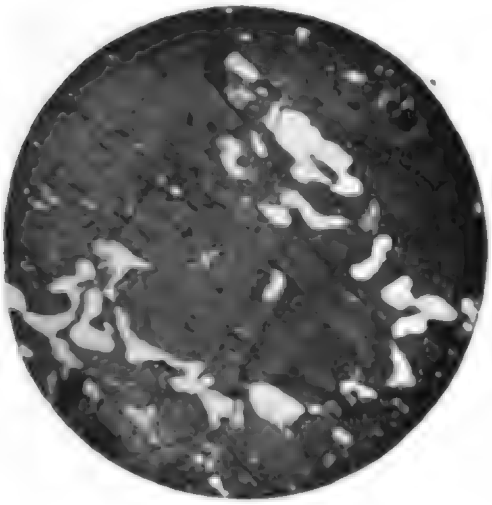

FIG. 1.

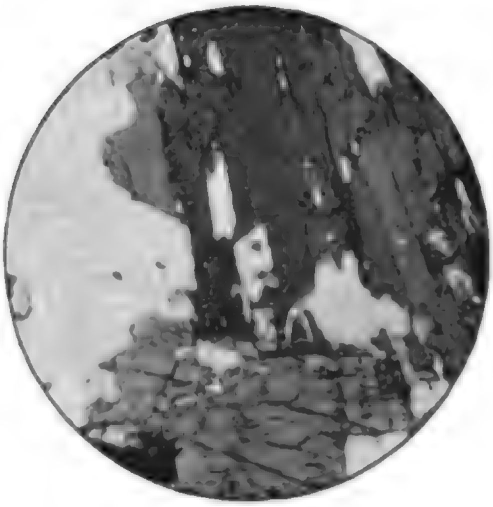

FIG. 2.

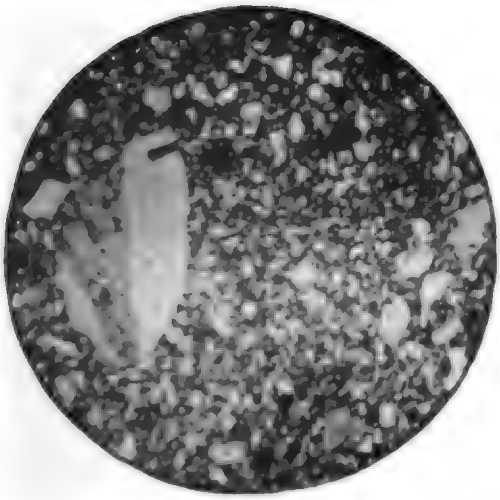

FIG. 3.

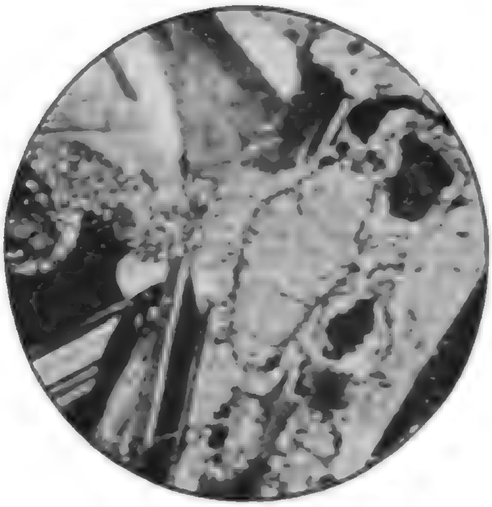

FIG. 4.

FIG. 1.—Micropoikilitic structure in hornblende of diorite—West Arm, Lake Nipissing. × 65.

FIG. 2.—Primary epidote in biotite of quartz-mica-diorite-gneiss—Gordon creek, four miles from Long Sault, Lake Timiskaming. × 65.

FIG. 3.—Character and position of included fragments in typical greywacke—Little river, Lak Timiskaming. × 65.

FIG. 4.—Rim of chlorite, surrounding augite of diabase—Fanny Lake. × 52.

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the prevalent granitite, the individuals showing the more advanced stages of decomposition bearing a marked macroscopical resemblance to those of the ordinary green trichroic hornblende usually noticed in these Archæan rocks. The rock presents the usual reddish or greyish colours, and, where highly differentiated, exhibits the usual interfoliation of lighter and darker coloured bands, although the lenticular areas or patches of the former are relatively less abundant and of smaller extent than those of darker hue. The structure of the rock is holocrystalline; it is composed of quartz, orthoclase, plagioclase, microcline, biotite and hornblende as the chief or essential constituents, together with a much smaller quantity of ilmenite (in part altered to leucoxene), magnetite, sphene, epidote, apatite and zircon, as accessory or accidental constituents; while chlorite, calcite, and sericite usually occur in more or less abundance as secondary products of decomposition. Hornblende is the most abundant ferromagnesian mineral in the more basic portions, while biotite predominates in the lighter coloured patches. The rock presents no unusual features as regards crush phenomena, the component individuals of feldspar and quartz usually showing little evidence of having been subjected to any very considerable pressure subsequent to consolidation.

D. *Hornblende-granite-gneisses.*—This facies of rock seems to be of rather limited and rare occurrence in the district under description, and the specimens from which the thin sections were prepared for purposes of study were obtained in close proximity to masses of basic pyroxenic or hornblendic material. Their composition and association has suggested that the rock may represent a commingling or transference of material, through fusion, of the substance of both rocks. The rocks thus classified resemble very closely the hornblende-granites with which they are intimately related. The most common of the essential constituents are quartz, orthoclase, microcline, plagioclase and hornblende, with sphene, apatite, iron ore, zircon, epidote and garnet as accessory minerals.

The colour varies greatly, depending largely on the composition, the more basic portions being dark-greenish to almost black, while the acidic bands are greyish or reddish.

Certain of the more massive and homogeneous varieties of these rocks have a distinct flesh-red colour, with a greenish tinge given by the prevalence of the hornblende.

In common with the rest of the gneisses these rocks have been subjected to pressure of varying intensity, resulting in the granulation of the quartz and feldspar.

II.—Syenite Gneisses.

These do not appear to have many representatives amongst the rocks of the region. Those observed correspond to the mica-syenites of the massive plutonic igneous rocks and may be termed:—

Mica-syenite-gneiss.—This is a holocrystalline foliated rock characterized by the almost total absence of quartz, and the presence of biotite as the principal ferro-magnesian constituent.

Orthoclase is the prevailing feldspar in the typical examples, but in the one specimen which was examined a plagioclase (oligoclase or albite) was found to constitute nearly 50 per cent of the feldspar present in the section.

These rocks are undoubtedly the foliated equivalents of the massive mica-syenites, which, as is well known, frequently contain a considerable quantity of albite in addition to the orthoclase and biotite.

III.—Diorite Gneisses.

Var. (a) Quartz-mica-diorite-gneiss.—Macroscopically this rock is of a dark-grey almost black colour, very evenly foliated, and presenting brightly glistening cleavage surfaces. Sometimes very narrow interfoliated bands are more acid in composition, and have a reddish or greyish tinge owing to the presence of a considerable quantity of feldspar and quartz, more or less stained by hydrous oxide of iron.

Both in the field and under the microscope these are seen to merge gradually into the more basic varieties of the granite-gneisses, from which they differ chiefly in that the orthoclase is replaced by plagioclase as the predominating feldspathic constituent, while hornblende, instead of biotite, is present as the principal ferro-magnesian mineral, occurring in considerable quantity even in the most basic phases of the rock, while both these minerals are always abundant enough to characterize it. The constituent minerals are essentially identical with those noticed as present in the more basic types of granite-gneiss, differing only in the order of their relative abundance and importance. The coloured constituents, such as hornblende, biotite and sphene, make up the greater part of the rock, which is relatively much poorer in feldspar and quartz, the most important and abundant minerals in the granite-gneisses. The essential constituents usually noticed are plagioclase, orthoclase, quartz, hornblende and biotite. Microcline is very often present in subordinate amount. Primary epidote in very sharp idiomorphic crystals, embedded chiefly in unaltered biotite, and sometimes penetrated by wedge-like crystals of sphene or titanite, was frequently noticed. Of the accessory minerals, sphene, apatite and zircon are almost invariably present, while pyrite, magnetite, limonite, epidote and allanite likewise sometimes occur. These basic bands are undoubtedly integral portions of the same magma from which the more usual or prevailing granite-gneiss has solidified.

Var. (b) Dioritic Gneiss: Amphibolite.—It has been thought advisable for the purposes of distinction to use this term 'dioritic gneiss,' not as implying any difference in origin, but simply denoting that the rock thus classified does not form an integral or highly differentiated portion of the same magma from which the ordinary gneisses have solidified. It frequently occurs interfoliated, and often in dike-like forms, evidently representing portions of some pre-existing basic irruptive which has undergone excessive crushing and consequent recrystallization, as a result of the subsequent intrusion of the associated gneissic rocks classified as Laurentian. Macroscopically these rocks are fine-grained, very dark greenish-grey (almost black) in colour, with distinct foliation and schistosity. When broken the fresh surfaces show brightly glistening crystals and plates of hornblende and mica. The rock examined is composed chiefly of compact green trichroic hornblende and plagioclase. As is often the case with rocks which have undergone similar extensive recrystallization the triclinic feldspar present is very clear and glassy, showing a frequent and marked absence of the twinning or pressure lamallæ. When these are present, however, the extinction-angles shown are those characteristic of labradorite, while some of the unstriated grains may possibly represent orthoclase. The quartz present is proportionately very subordinate in quantity, and is often with difficulty distinguishable from the clear and sharply extinguishing feldspar. The biotite present occurs in intimate association with the hornblende, sometimes forming parallel intergrowths with this mineral; garnet and ilmenite, the latter mineral often surrounded by sphene, are likewise present. In several instances the same rock was traced directly and continuously into larger areas of practically unaltered gabbroic or diabasic material, of distinctly earlier genesis than the gneiss in which they are embedded.

Minerals of the Gneissic Rocks.

The minerals observed in the acidic and basic gneissic rocks are the following:—

Quartz
Orthoclase
Microcline
Plagioclase
Biotite
Hornblende
Epidote
Muscovite
Chlorite
Pyrite
Calcite
Sericite
Apatite
Titanite
Zircon
Garnet
Magnetite
Hematite
Ilmenite
Leucoxene
Limonite
Zoisite
Talc
Tourmaline
Allanite
Rutile
Cyanite
Graphite
Fibrolite
Augite

Of these the quartz, orthoclase, plagioclase, biotite, hornblende, epidote and muscovite may be regarded as essential, and the remainder either accessory or secondary constituents.

Classification of Gneissic Rocks mapped as Laurentian on the Nipissing and Timiskaming Sheets (Nos. 131 and 138), showing their relations to the Normal Massive Types of Igneous (Plutonic) Rocks.

A. MASSIVE IGNEOUS (PLUTONIC) TYPES.			B. GNEISSIC EQUIVALENTS.	
ACIDIC DIVISION.				
I. GRANITE.	GRANITE, proper.	=	A. GRANITE-GNEISS.	
	MUSCOVITE-GRANITE.	=	B. MUSCOVITE-GRANITE-GNEISS.	
	GRANITITE.	=	C. GRANITITE-GNEISS.	
			I. Micaceous.	
			var. (a) Biotite and Epidote.	A$_1$ Fresh and unaltered. Epidote nearly all primary* B$_1$ Crushed and altered. Much secondary epidote.
			var. (b) Biotite with little or no Epidote.	
			var. (c) Biotite, with Cyanite, Garnet, Graphite, etc.	
			II. Hornblendic.	
			var. (d) Hornblende and Biotite.	
	HORNBLENDE-GRANITE.	=	D. HORNBLENDE-GRANITE-GNEISS.	
II. SYENITE.	MICA-SYENITE.	=	MICA-SYENITE-GNEISS.	
BASIC DIVISION.				
III. DIORITE.	MICA-DIORITE. Quartz-Mica-Diorite.	=	Quartz-Mica-Diorite-Gneiss.	Var. (a) Quartz-mica-diorite-gneiss, integral and extremely basic portions of the same magma from which the more common granite-gneisses have solidified. Var. (b) Dioritic Gneiss = Amphibolite, representing interfoliated basic irruptives, which, of earlier genesis, have been crushed and recrystallized by the intrusion of the ordinary or prevailing gneissic rocks.

*Primary epidote is present in both A$_1$ and B$_1$, but in B$_1$ it is largely mixed with secondary epidote derived from the alteration of the feldspar. Primary epidote is likewise very constantly present in the quartz-mica-diorite-gneisses, the crystals being both sharp and perfectly developed.

Quartz.—This is, in general, a very abundant mineral in the gneisses of the district. Only in a few cases were granitic specimens observed in which the absence of quartz would lead to their being grouped with the syenites. It enters largely into the composition of the basic rocks, allying them to the quartz-diorites and quartz-mica-diorites. In its general character it does not differ from the ordinary granitic variety, but is, of course, much crushed, stretched and granulated in those gneisses which have been subjected to intense dynamic action.

It appears to fill in the spaces between the feldspar of the rock, and, consequently, to have crystallized out of the magma after they were formed. This is especially noticeable in many of the basic or dioritic gneisses. Distinct crystals of quartz have not been observed in the rocks examined, the mineral occurring in the form of irregular grains.

The quartz grains, as usual, always exhibit the effects of dynamic action in a much more marked degree than do the feldspars. A granophyric intergrowth with feldspar is of very common occurrence. Inclusions are frequent. Sometimes the quartz occurs in grains scattered through hornblende, the individual grains having no regular arrangement or orientation with respect to one another or to their host. Such a structure has been named 'poikilitic' by the late Dr. George H. Williams.*

Orthoclase.—This is the most abundant of the feldspars which occur in these rocks. It usually forms irregular grains interlocked with the other feldspars and quartz, although in a few instances porphyritic individuals occur, which are sometimes twinned. It is seldom quite clear and fresh-looking, but usually turbid in appearance, and more or less filled with little scales of sericite and granules and crystals of epidote and zoisite, the products of its decomposition.

In those specimens representing rocks which have evidently been subjected to intense dynamic action the orthoclase shows a marked tendency to pass into microcline. Inclusions of the other minerals present in the rock are of frequent occurrence, and intergrowths with triclinic feldspars were also noted. It is often stained with hydrous oxides of iron, giving brownish or reddish tints to the rock. In common with the other feldspars it has escaped to a large extent the results of dynamic action, rocks in which the quartz has been completely granulated frequently preserving large grains of the feldspars which show only a few cracks and a more or less pronounced undulatory extinction.

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*On the Use of the Terms Poikilitic and Micropoikilitic in Petrography; Journal of Geology, vol. I, No. 2, pp. 176-179.

Microcline.—This is a very abundant constituent of the granitic gneisses, especially of those which have been greatly crushed and granulated. Teall has recently announced that the result of his investigations of the microcline in the older Deeside (Cairnshee) granite of the Highlands of Scotland 'lend no support to the view that microcline may be developed from orthoclase by dynamic or any other action, but are in accordance with the theory of Michel, Lévy and Mallard, that orthoclase is microcline in which the polysynthetic twinning is on a sub-microscopical scale.'

The constant relationship which exists between the quantity of microcline in a given rock and the degree of pressure to which the rock has been subjected, as brought out by microscopic examination, is of too marked a character to be ignored, and instances may frequently be observed, where, when a large individual of orthoclase has been peripherally granulated, the fragments detached from the parent individual show to perfection the typical cross-hatching of microcline, whilst the centre is quite free from striations and exhibits the ordinary characters of orthoclase. There is not, in such instances, a gradual transition from one structure to the other, the cross-hatching in the detached bit of granulated material next to the parent individual terminating as abruptly against the fractures which separate them from it as do the striæ induced by pressure in a plagioclase individual against cracks traversing the crystal. Where evidences of pressure are unmistakably present, but fracturing has not actually taken place, the gradation may be seen from the normal orthoclase, through a 'moire structure' to the typical cross-hatching. Plate IV., Figs. 2 and 3.

Thus, whether microcline and orthoclase be identical or dimorphous, (a question which cannot be discussed here) the scarcity of the former in unaltered rocks, and its marked abundance in those which have been subjected to pressure, together with the peculiar manner in which it has been observed to occur in individual instances mentioned above, seems to prove rather conclusively that microcline structure at least can be, and is, produced in the feldspar now known as orthoclase and not showing that structure as the result of pressure. It seems, too, reasonable to suppose that, if orthoclase be microcline with a sub-microscopic twinned structure, we should find various gradations in the same section from the microscopically invisible structure, through exceedingly fine striation, to the distinctly visible and sometimes quite coarse structure characterizing what we call microcline.

Instead of this we find that when a crystal which we call orthoclase is subjected to pressure a peculiar wavy structure appears in

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it, analogous to the strain shadows of quartz as seen in the thin section; the grain or crystal, when carefully examined under the microscope, being evidently under strain and undergoing deformation. This wavy structure gradually merges into the typical cross-hatched one. In fact many of the arguments advanced and facts cited in favour of the theory that microcline and orthoclase are identical seem to point strongly to the conclusion that this is not the case, but that microcline represents a re-arrangement of the orthoclase molecule induced by pressure.

Cases where areas of feldspar with typical microcline structure occur, included in unaltered and uncrushed orthoclase individuals, may be regarded as analogous to intergrowths of the ordinary triclinic and monoclinic feldspars.

Plagioclase.—In the granitic and syenitic gneisses plagioclase is tolerably abundant, in the case of the mica-syenite-gneiss from Cross lake constituting nearly one-half of the feldspar present. No direct chemical determinations have been made, but when the angles of extinction have been measured these indicate that the feldspar is either an oligoclase or an andesite.

As a general rule the proportion of the plagioclase present increases with the basicity of the rock, and it, of course, predominates in the diorite-gneisses of the region. In these rocks it is, apparently, chiefly a labradorite. It is usually well twinned, this twinning being due to pressure in many cases.

Alteration to calcite was frequently observed, also typical saussuritization of the more basic varieties, with formation of zoisite, epidote and sericite. Poikilitic and micropoikilitic structures are sometimes seen.

In some of the basic gneisses which may possibly have resulted from the metamorphosis of a basic irruptive the feldspar is frequently very clear and glassy, with numerous unstriated grains which are, however, probably plagioclase. It is somewhat difficult, in such cases, to distinguish between the glassy feldspar and the quartz.

Biotite.—This is by far the most abundant ferro-magnesian constituent of the granitic and syenitic gneisses, and also enters quite freely into the composition of the basic varieties. The primary biotite occurs in two forms, as large broad plates aggregated together, and as isolated smaller plates having a general parallel arrangement in the rock.

Crystals with perfect crystallographic boundaries were not observed. Mechanical deformations of the plates are well seen in rocks which show the general effects of dynamic action.

In most instances it is remarkably fresh and is intimately associated with epidote, large, fresh, isolated crystals of which are frequently enclosed in the unaltered biotite. In colour it is usually a deep reddish-brown, in some cases inclining to a copper-red, and is very strongly pleochroic, from pale straw-yellow to a deep reddish-brown. When more or less altered to chlorite it assumes various tints of green.

Occasionally, in the hornblende-granite-gneisses and diorite-gneisses, it is intimately associated with the hornblende. In those rocks which contain both micas the biotite and muscovite occur intergrown with each other, the plates of each variety being sharply defined.

Frequently, however, by a leaching-out process, the iron has been so far removed from the biotite as to cause it to assume a very light colour; indeed in some sections it is difficult to determine whether certain individuals are to be regarded as bleached biotite or as original muscovite.

In addition to the biotite, which is of undoubted primary origin, little scales of secondary biotite may often be observed developed along shear-planes in certain of the greatly crushed and stretched gneisses. The biotite holds numerous inclusions of apatite, zircon, &c., which are commonly surrounded by dark, pleochroic halos.

Hornblende.—This appears to be a comparatively rare mineral in those granitic and syenitic gneisses which have been examined from this region. In two instances it is tolerably abundant, but in most cases where it has been observed only one or two minute grains could be detected in a single thin section of the rock.

In the basic or dioritic gneisses it is, of course, a very abundant mineral. In these rocks it occurs as the compact variety chiefly, actinolitic forms being rare. It forms, as a general rule, rather irregular individuals aggregated together, although occasionally some may be seen having well defined crystallographic boundaries.

It possesses good cleavage and is very strongly pleochroic. The absorption is usually $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$ generally $\mathfrak{a} =$ greenish yellow, $\mathfrak{b} =$ dark yellowish green, and $\mathfrak{c} =$ deep bluish-green. Twinning is a common feature of the mineral.

The hornblende is always intimately associated with the biotite and epidote when these latter minerals are present in the rock. In several instances the extinction angle was measured and found to vary from 17½° to 19°.

Inclusions of feldspar, quartz, zircon, apatite, titanite, &c., are very common and are frequently arranged in such a manner as to give to the hornblende-gneiss a typical micropoikilitic structure. Plate II.,

Fig. 1. As in the case of the biotite the inclusions of apatite and zircon are often surrounded by well defined pleochroic halos. Alteration to chloritic and epidotic material was observed, accompanied by the deposition of carbonates.

No instances of augite cores occurring in the hornblende were noticed, nor any direct evidence of the latter mineral having originated from the former; although in some few instances this might be suspected from the fact that the interior of the crystal is of a paler colour than the exterior portion.

Epidote.—Next to the biotite this is by far the most abundant of the coloured constituents of the granitic gneisses, and it also enters largely into the composition of the more basic hornblendic ones. In addition to the ordinary occurrence of the epidote as an alteration product we have also the strongest evidence that it exists in a large number of cases as an original and important constituent of the rock mass.

The manner in which the perfectly fresh crystals possessing sharply defined outlines occur, enclosed by wholly unaltered biotite in rocks which have been subjected to only a slight degree of pressure, admits of no reasonable doubt as to their primary nature. An inspection of the accompanying plate, (Plate II., Fig. 2), will bring this point out very clearly. The mineral is usually of a bright yellow colour, very strongly pleochroic, and possessing the usual high relief and brilliant polarization colours, except in sections parallel to the orthopinacoid, which exhibit bluish and yellowish tints between crossed nicols. It occurs both in crystals and irregular grains, the former often having, as already stated, very sharply defined outlines.

The corrosion phenomena noted by Dr. Adams in epidote from the Yukon river* are shown to perfection in some of the individuals. The crystal sections are usually bounded by the prism planes M, r, and T. Good cleavages were observed parallel to M and T, the angle between them being about 115°.

Twins are of common occurrence. The crystals occasionally contain cores of a pleochroic brownish substance which is probably allanite, but no thoroughly typical examples of that mineral were detected.

Nondescript cores, which may represent augite surrounded by rims of epidote, were occasionally seen in the thin sections. Secondary epidote frequently occurs in the groundmass of the more altered rocks, associated with chlorite, as the result of the mutual reaction of the feldspars and bisilicates. It also forms small crystals and granules in the decomposing feldspars, together with zoisite, sericite and carbonates, as one of the products of their saussuritization. Many cases occur in highly granulated rocks where it is almost impossible to say what is primary and what secondary epidote. Frequently, however, in rocks which have suffered extreme crushing and are filled with secondary epidote granules, large epidotes may be observed broken and faulted like the other constituents, proving that they existed before the rock was subjected to the dynamic action.

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*Can. Rec. Sc. vol. IV., pp. 344-358, 1890-91, also Annual Report Geol. Surv. Can., vol. III. (N.S.), Part I, Appendix V (N.S.), p. 237 B., 1887-88.

Muscovite.—Both primary and secondary muscovite occur in these gneisses, and it is often difficult in a particular instance to determine to which of these two classes the mica is to be referred. Frequently broad fresh laminæ of muscovite are intimately intergrown with deep-brown fresh biotite, and in such cases are undoubtedly of primary origin.

The variety of the mineral referred to here is muscovite proper, occurring in broad plates or laminæ, as distinguished from the fine scales of sericite resulting from the alteration of plagioclase, &c. It possesses the usual bright polarization colours and other physical characters common to the species, and no unusual features were observed in the specimens examined.

Chlorite.—(Taken as a general group name).—This is the common alteration product of the biotite and hornblende of these rocks. It polarizes in the usual dull bluish tints.

Many of the gneisses owe their green colour to this mineral, which gives them a very deceptive appearance, acid granitic rocks very often closely resembling, at first sight, some massive altered basic irruptive.

Pyrite.—Is of common occurrence in all the gneisses, particularly in the more basic ones. The red and brown oxides of iron which so frequently stain the rocks can often be traced to this source.

Calcite.—This mineral is abundant where alteration of soda-lime feldspar has proceeded to any extent. In such cases it forms large, irregular, brilliantly polarizing patches throughout the thin section. Its abundance in some specimens, *e. g.*, in the hornblende-granite-gneiss from the south end of Opimika narrows, is rather remarkable, as this rock does not seem to have been greatly altered. In such instances it may possibly be of primary origin.

Sericite.—This is an abundant product of the saussuritization of the feldspars, forming fine, brilliantly polarizing scales, intimately associated with zoisite, calcite, &c. Some of the material referred to as sericite in the description of these rocks may possibly be talc, as it is difficult to distinguish between these two minerals under the microscope.

Apatite.—This mineral is of frequent occurrence in the acidic and basic gneisses. It is mostly in the form of stout and short or long and slender prisms, but grains with extremely irregular and more or less rounded outlines also occur. The large stout prisms are especially characteristic of the diorite-gneisses.

Titanite (*Sphene*).—Remarkable crystals of this mineral were observed in some of the rocks examined. They are of unusually large size, deep clove-brown in colour, and intensely pleochroic, and, as is usual in such dark-coloured varieties, exhibit their brilliant interference colours to perfection. Twinning was frequently observed.

The mineral is especially abundant in those rocks in whose composition hornblende occupies a prominent place. It occurs in irregular grains of varying size, as well as in the well formed crystals just mentioned. Little crystals were observed penetrating the epidote crystals and also included in hornblende and biotite. It frequently forms fine-grained granular aggregates of considerable size, and is present in nearly all the rocks described, both basic and acidic.

Zircon.—This mineral is also of widespread occurrence in the gneisses. The crystals are usually well developed, and often of large size. When embedded in the biotite or hornblende it is usually surrounded by a pleochroic halo.

Garnet.—This is by no means as abundant a constituent of the gneissic rocks of this region as was formerly supposed, although in certain localities it is extremely plentiful. It occurs in the granitite-gneiss containing cyanite, and also in several of the more or less altered basic-gneissic hornblende rocks. It is usually in fresh irregular grains and aggregates, frequently of large size, much fractured, and of a light pinkish colour in thin sections. The optical anomalies which have elsewhere been frequently noted were not observed in the present instances, all the grains appearing to be completely isotropic. Distinct crystals were very rarely seen.

Magnetite.—As stated elsewhere the scarcity of iron ore in the granitic gneisses is a remarkable feature in their composition. In a few instances isolated grains were tested and found to be magnetic.

Hematite.—This is frequently present in the form of thin plates with hexagonal outlines, and in irregular scales. It is often developed along the cleavage planes of the biotite.

Ilmenite.—Generally speaking this is the iron ore which is present in the diorite-gneisses, and is almost invariably accompanied by its alternation product, leucoxene. It may be regarded as one of the essential ingredients of these rocks. The peculiar brownish tints so often seen in the plagioclase are probably very often due to dust-like particles of this mineral included in them.

Leucoxene.—This is always an alteration product of titanic iron ores or rutile. The grains of ilmenite are sometimes completely replaced by whitish or yellowish almost opaque masses of this mineral. A peculiar cross-hatched structure was sometimes observed, probably due to sagenitic growth of rutile which previously existed in the ilmenite individual from which the leucoxene was derived.

Limonite.—The irregular deep-brown stains which frequently permeate the various minerals, especially the feldspars, are probably in most cases due to the presence of this mineral.

Zoisite.—Accompanies epidote as the result of saussuritization of the feldspars, usually in quite small individuals which present no unusual features.

Talc.—In a few of the more squeezed and altered gneisses scales were observed which seem to correspond in their general characters with this species, as distinguished from sericite, but it is difficult to discriminate between these two minerals.

Tourmaline.—Two or three columnar strongly pleochroic individuals of this mineral were observed in one of the gneisses examined.

Allanite.—Whilst not particularly abundant many good examples of this mineral were observed, more especially in those granite-gneisses in which idiomorphic primary epidotes are plentiful. It occurs in the reddish-brown pleochroic individuals in the centres of epidote crystals with which it is in parallel orientation. These occurrences are of precisely similar character to those described by Hobbs in the Maryland granites.

Rutile.—This mineral was observed in a few instances in the form of very minute, slender needles penetrating the biotite.

Cyanite.—Occurs in rather short flat-bladed crystals, which rarely show sharply defined faces in the prism zone, commonly forming irregular columnar individuals. A few of the smaller crystals show terminations, but with very rough faces.

The colour is usually light-bluish or greenish, but occasional crystals show a deep blue centre with a white margin. Some individuals measure half an inch across and an inch in length. It is best developed in those portions of the rock which are free from biotite, and consequently of a lighter colour. In the darker portions of the rock it is frequently intergrown with the biotite. The individuals are often bent and hold many inclusions, particularly of pyrite, biotite, quartz and graphite.

Under the microscope the sections are transparent and generally colourless, but patches of a light-blue colour occur here and there. These patches exhibit a pleochroism (light-blue to colourless) which is not noticeable in the colourless portions of the crystals. The cleavage parallel to M and T does not traverse the entire section as a rule. In longitudinal sections the parting parallel to P is also clearly shown. As is invariably the case the cyanite is accompanied by garnet.

Graphite.—This mineral occurs in some quantity in the cyanite-gneiss in the form of irregular flakes, rarely with rude hexagonal outlines. A few flakes were observed to be nearly a quarter of an inch in diameter.

Fibrolite.—Only a few specimens of the cyanite-gneiss were collected from the cuttings on the Canadian Pacific railway in the vicinity of Les Erables rapids and Snake creek, on the Ottawa river, and these show no fibrolite, but it is almost certain that this mineral, which accompanies the cyanite in the similar rock from near Wanapitei station, will be found associated with it in the area.

Augite.—This mineral, as elsewhere noted, is almost, if not entirely, absent from those gneisses which have been microscopically examined. In certain specimens a few skeleton forms, entirely filled with alteration products, were observed, which may originally have been pyroxene, but this is by no means proved. The hornblende was carefully examined to see if there were any traces of pyroxene cores in it, but no certain evidence of this was obtained, although in some cases it was observed that the exterior of the hornblende individual was of a darker colour than the central portion.

GRENVILLE SERIES.

The name Grenville Series was the distinctive title applied in 1863* by Sir William Logan to the series of crystalline rocks so extensively and well exposed in the region on the north side of the Ottawa in the vicinity of the Augmentation and village of Grenville. These were referred to as Middle Laurentian and supposed to conformably overlie the Lower Laurentian or Fundamental Gneiss. The rocks thus classified comprise a great variety of gneisses with which are associated considerable volumes of crystalline limestone, and a detailed map was published showing the distribution of the component bands.* Many reasons were adduced as evidence for regarding the whole series as greatly metamorphosed sedimentary strata. These proofs had reference chiefly to the banded or foliated character of many of the composing masses, believed to represent the surviving traces of the parallelism due to original sedimentation, the presence of large and important beds of limestone, together with the occurrence in some of these bands of forms described as representing organisms of low type. Subsequent examination in the field, supplemented by the detailed petrographical studies rendered possible by the recent perfection of the microscopic methods of research, have, however, revealed the fact that while certain of the fine-grained, light-greyish, rusty-weathering gneisses are closely allied in structure and composition to ordinary shale or slate, other rocks, representing a very much greater volume of the whole series, are undoubtedly the foliated equivalents of the ordinary plutonic irruptives.†

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*Geology of Canada, (1863), p. 839.

*Atlas, Geology of Canada, (1863), Map No. 1.

In the area covered by the accompanying map-sheets the line of subdivision between what has usually been regarded as Lower Laurentian and the Grenville Series was described by Sir William Logan, in 1844, as occurring somewhere in the vicinity of the Mattawa river. The supposed line of boundary was based on the occurrence at certain points of isolated masses of crystalline limestone, but these have since been found to be in intimate association with rocks which are believed, with some confidence, to be the foliated equivalents of ordinary granites and diorites.

In the area under description only one very limited occurrence of the fine-grained and evenly banded light-greyish gneisses usually associated with the Grenville series was noticed, consisting of a small band interfoliated with the ordinary reddish granite-gneisses, a little over two miles east of Rutherglen station on the Canadian Pacific railway. The strike of this band is about N. 20° W., with a dip to the northeast at a high angle. The hand specimen represents a fine-grained evenly foliated, rusty-weathering, greyish, graphitic gneiss. Under the microscope it is a fine-grained admixture of interlocking grains of feldspar, quartz, and a rather pale-coloured bleached biotite, together with smaller quantities of pyrite, graphite, rutile, and a mineral closely resembling zoisite in minute crystals, arranged in nests composed of aggregates of crystals and crystal fragments running parallel with the foliation. The rock has evidently been subjected to intense and long continued dynamic action, the foliation being pronounced, while the recrystallization has been so complete as to mask much of its original structure. It bears a marked microscopical as well as macroscopical resemblance to the sillimanite gneisses described by Dr. Adams.*

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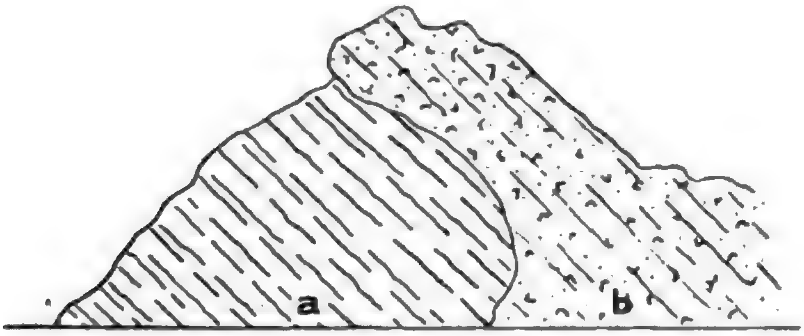
†Adams. A Further Contribution to our knowledge of the Laurentian, Am Journ. Sci., July, 1895.

The most important band of crystalline limestone noticed in the whole district occurs at the foot of Lake Talon, an important expansion of the Mattawa river. The presence of this band was first noted by Bigsby† in 1820, and later in 1844 by Logan. Dr. Bell, in 1873, also gave a short description of its mode of occurrence.‡ The rock consists of whitish crystalline limestone with small thickly disseminated specks and patches of green serpentine. It is first noticed on the south side of the lake a short distance above the outlet, occupying the points along the shore, while the massive reddish granitite-gneiss rises into rounded hills behind. The limestone, as far as can be ascertained on account of the massive texture of the gneiss, occurs as an interfoliation, dipping S. 8° E. < 25. Farther down towards the chute the rock contains a good deal of serpentine in addition to some other impurities, and occurs seemingly as a large irregular rounded patch in the gneiss. At the narrows, a short distance above the Talon chute, the contact between the crystalline limestone and massive rather indistinctly foliated red granite-gneiss is well shown, the former dipping N. 74° E. < 20° while the latter, with a nearly east-and-west strike, overtops or flows over the mass of the crystalline limestone, the indistinct foliation of the gneiss conforming in general with the line of junction between the two rocks. See Fig. 1.

Fig. 1.



Sketch section showing structure of crystalline limestone (a) and massive red granite gneiss (b), near Talon chute, Mattawa river.

At the Talon chute there are two channels by which the lake discharges into the gorge below. The largest of these channels is situated near the north side, while the southern one has been excavated along a band of ophicalcite, seventy feet in thickness, intercalated with the gneiss and dipping in a southerly direction < 25°.

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*Annual Report, Geol. Surv. Can., vol. VIII. (N.S.), Part J.

†Shoe and Canoe. vol. I. London, 1850.

‡Report of Progress, Geol Surv. Can., 1876-77, p. 207.

Smaller bands and patches of crystalline limestone likewise occur on three of the Manitou group of islands in the eastern portion of Lake Nipissing. On the west side of the most southerly of these islands beds of a beautiful light salmon-pink crystalline limestone occur, containing radiating crystallizations of dark-green hornblende, black biotite, and yellowish-green epidote. The strike is about N. 80° E. and the angle of dip is about 65°. This is associated with the prevailing rather fine-grained dark-reddish and green granitite-gneiss.

On the east side of the Great Manitou island (Newman island), a few chains south of the northeast point, there is a layer or bed of pinkish limestone, weathering yellow, reddish and greyish. The strike of the dark-red and green granitite-gneiss is about S. 60° E. and the dip southeast $< 45°$. On the west side of the most easterly of the Manitou islands, about the centre of the island, beds and patches of pinkish and whitish limestone are embedded in the dark-red and green granitite which has a strike of S. 5° E. and a dip to the east $< 45°$.

HURONIAN.

The name Huronian was adopted by Sir William Logan and Dr. T. Sterry Hunt in 1855* to include the clastic rocks believed to overlie the Laurentian gneisses in the districts adjacent to Lakes Huron and Superior.

The area included by the present report exhibits large tracts of country underlain by pyroclastic and epiclastic rocks identical in lithological character with those described as Huronian by Murray in 1856. It forms, in fact, the northeasterly extension of the same belt, which has been traced with practical continuity from what is generally termed the 'typical' area on the north shore of Lake Huron. The inclusion of these rocks under the name 'Algonkain,' shows a tendency on the part of some geologists to revert to the erroneous grouping of Huronian, Animike and Keweenawan as integral portions of a single system or series of formations, in spite of the pronounced haitus known even then to exist, though perhaps not appreciated to its full extent by Sir William Logan. As has been pointed out by Dr. Dawson † and others, the proposed use of the term Algonkian in the same extended sense is both unnecessary and misleading, and it should therefore be deprecated. Its adoption disregards not only the zealous and accurate work of many trained observers over extended areas characterized by the presence of these

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*Esquisse Géoligique du Canada. Paris, 1855, p. 29.

†Presidential Address to the Geological Section, B.A.A.S., Toronto meeting. 1897.

Archæan rocks, but would also supplant a useful and well known term, of which the priority remains unquestioned, by a name which is at once needless and indefinite. No attempt has been made to correlate the rocks here described as Huronian with certain series or groups which have been lately and ably reported upon under the new conditions since the use of the microscope has made an accurate description of the various component rock masses not only possible but imperative. It is also regarded as premature as yet to anticipate the results of further and more complete microscopical and stratigraphical examinations of the Huronian, Grenville, Hastings, Keewatin and Coutchiching series.

The Huronian rocks, which are extensively and widely developed in the northwestern part of the region under description, naturally admit of a three-fold sub-division, the component members following one another in undisturbed succession, each showing a gradual and perfect transition upward into the succeeding member. The rocks occur for the most part in slightly undulating anticlinal and synclinal folds, except in the vicinity of certain large irruptive masses, where considerable disturbance as well as alteration is found as a result of their intrusion. At the base of the series is a breccia-conglomerate, containing pebbles and fragments, often angular, though usually subangular or rounded in outline, of granitite diabase, diorite, etc., embedded in a matrix composed of the same materials in a finer state of division, while the more minute interstices are filled up with scales and flakes of chlorite and sericite. Where this matrix forms a considerable portion of the rock the abundance of these decomposition products gives a prevailing dark-green colour to the whole mass. This rock has in previous reports been referred to as 'slate conglomerate' or 'chloritic slate conglomerate,' a name first proposed and used by Logan.* This coarse fragmental rock passes upward into a dark greenish-grey greywacké or feldspathic sandstone, in which few if any fragments are macroscopically apparent. This in turn merges above into an exceedingly compact and fine-grained rock of essentially similar composition, which gradually assumes a banded and slaty character, the planes of cleavage, when present, corresponding in most instances with the evidences of original sedimentation as revealed by the colour stripings. Superimposed upon these, usually without any sharp line of division, although at times there is an abrupt change, is a quartzite-grit, made up chiefly of fragments of granitic quartz with some of feldspar, all usually more or less rounded and continued in a feldspathic matrix, now largely altered to yellowish-green sericite.

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*Report of Progress, Geol. Surv. Can., 1845-46, p. 67.

The rock is generally yellowish-green in colour owing to the abundance of sericite, the scales of which are often macroscopically apparent in the matrix. On this account it has been usual to refer to the rock as a sea-green quartzite. Occasionally it is of a flesh-red colour, when it is with difficulty distinguished from ordinary granite. It occurs in massive much jointed beds, the stratification at times being shown only by a parallel disposition of certain coarser or conglomeratic bands. It is occasionally fine-grained but usually approaches the character of a grit or fine conglomerate.

Until very recently it was a matter of general belief, based on previous descriptions and reports, that the source of such clastic material was to be traced to the breaking down of the gneissic or foliated crystalline rocks usually classified as Lower Laurentian. The writers repeatedly insisted that gneissic pebbles, distinctly referable to the Laurentian, formed the most abundant coarse fragmentary material in the basal beds of the Huronian. Later geological research in this and neighbouring Archæan areas has shown, however, that such statements are largely erroneous, as foliated fragments are only very occasionally represented and in most cases are entirely absent, while those of a somewnat coarse-grained aplitic granite make up the greater portion of many of these conglomeratic rock masses. The examination likewise of the line of junction between the gneisses and the granites constituting the Laurentian of this district on the one hand, and the breccia-conglomerates and slates of the Huronian on the other, has shown that the former were in a plastic or softened condition after the hardening of the Huronian sediments.*

Most geologists were inclined, despite these opposing facts, to believe that the Laurentian gneisses and granites constituted the original floor or basement upon which the Huronian sediments were deposited and from which their material was derived. The present attitude of these rocks, moreover, was explained as due to the instability of the earth's first-formed crust allowing and favouring a settlement of any overlying clastic material, accompanied as it must have been by frequent and repeated upwellings of the molten magma from beneath. These unsettled conditions were further accentuated by extensive fracturing and crumpling as a result of the earth's secular refrigeration, all combining to bring about the conditions and phenomena now witnessed along the line of junction between the Laurentian and Huronian rocks.

Careful search has been made for localities in which the underlying basement might have escaped this seemingly wide-spread disturbance, but apparently in vain. Pumpelly and Van Hise* have described what they have called a basal conglomerate reposing upon a fundamental complex of crystalline schists and granite, as exhibited on two small islands near the north shore of Lake Huron, a short distance east of Thessalon, Ontario. A difference of opinion, however, exists concerning the interpretation of this section, and the fact that the granite from which the pebbles in the conglomerate are believed to have been derived pierces and alters the slaty rock overlying the conglomerate, seems to show clearly that the correlation of this granite with that constituting the pebbles in the conglomerate is decidedly at fault.†

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*Vide ante, also American Geologist, July, 1890, pp. 19-32. Bull. Geol. Soc. Am., vol. IV., pp. 313-332.

In spite, however, of the generally irruptive character of the line of junction between the Laurentian and Huronian, it was confidently anticipated by even those who believed in the intrusive character of the Laurentian gneisses that in some place an undisturbed contact would be ultimately found. The detailed geological examination of the region to the northeast of Lake Huron, carried on for the last ten years by the author of this report, has furnished abundant proofs of the pyroclastic character of the rocks composing the two lower members of the Huronian. The breccia-conglomerate, greywacke-and slates evidently represented the graded forms resulting from the consolidation of volcanic ejectamenta showered out and spread upon the bottom of a shallow ocean, and there somewhat rounded and otherwise modified as a result of aqueous action. In many cases, however, these rocks are so intimately associated with materials resulting from processes of ordinary aqueous erosion and deposition, that, in most instances, it is extremely difficult if not impossible to make a separation. The fragments contained in the breccia-conglomerate are, as has been shown, composed of rocks of igneous or plutonic origin and in no way distinctly referable to any Laurentian strata now exposed at the earth's surface in the same area, while the frequent intimate association of this coarse fragmental rock with large masses of diabase, gabbro and granitite, cannot be regarded as merely accidental. The earlier part of the Huronian period in this district was evidently a time of intense and long continued volcanic activity, and the greater portion of the rocks representing this lapse of time are pyroclastic in character.

True sedimentation on a large scale seems only to have been ushered in towards the close of the period, and the quartzite-grits and conglomerates prevailing towards the summit of the series are very typical examples of epiclastic material.

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*Am. Journ. Sci., III. vol. XLIII, pp. 224-232, March, 1892 ; also III. vol. XXXIV, 1887, pp. 207-216.

†Am. Journ. Sci., III. vol. XLIV., 1892, pp. 236-239 ; also Bull. Geol. Soc. Am. vol. IV., pp. 330-332.

The relations found to exist between this arkose and an underlying fundamental biotite-granite or granitite, as exposed on either side of Lake Timiskaming in the vicinity of Baie des Pères, indicate its derivation to be a result of the disintegration and degradation *in situ* of the underlying granite, showing a gradual and uninterrupted passage outward and upward from the parent mass. The nature and import of this passage was the subject of an illustrated paper prepared by the author and Mr. W. F. Ferrier, and presented at the Toronto meeting of the British Association for the Advancement of Science in August 1897.* A short resume of the interesting phenomena observed has already appeared in the Geological Magazine,† but the details, not only of the field relations of these rock masses but also of the petrographical examinations, will be found in that portion of this report dealing with the geological description of Lake Timiskaming. The relations between this granite and arkose are of rather unusual scientific interest, showing as they do the pre-Huronian existence of a basement or floor upon which these sediments were laid down and which in this portion at least has escaped the movements to which the Laurentian gneisses have been subjected.

The petrographical studies undertaken with the object of determining the origin, composition and minute structures of the various rock masses making up the bulk of the Huronian have been so numerous and detailed that it is impossible in the present report to give at length the description of each separate slide, especially as many of these prepared from specimens obtained at widely separated localities were afterwards ascertained to represent rocks presenting no essential points of difference. It will, therefore, doubtless be found sufficient to give a general description of each of the three members constituting the Huronian, at the same time pointing out the nature of the transitional sequence so frequently witnessed from one rock to the other.

Breccia-conglomerate.

The rock thus designated is identical with the 'slate conglomerate' or 'chloritic slate conglomerate' of the earlier reports of the Survey, described by Logan as following the Laurentian orthoclase-gneiss on Lake Timiskaming. The new name as proposed is preferred, as it indicates at once what is now confidently believed to be the true nature and origin of the large and important rock masses to which it is applied. This rock, especially where the finer matrix is abundant, is usually of a dark-greenish or greenish-grey colour, the colour deepening in proportion to the quantity of the greenish decomposition products which may have been developed. The immediate outer coating weathers from yellow through brown to almost black, although certain surfaces not exposed to the continued action of the atmosphere retain a light olive-green appearance. Beneath this dark outer surface is a layer, usually about one-eighth of an inch in thickness, composed of pale-yellowish decomposed material which evidently represents the usual saussuritic products resulting from the alteration of the large quantity of feldspar present in the rock. As a rule the rock is extremely massive, showing little or no evidence of lamination or stratification, while the coarser fragmental material is arranged in such a heterogeneous manner that it is exceedingly difficult to ascertain with any degree of certainty either the angle or direction of dip. Sometimes, however, it has a slaty or foliated structure as a result of pressure, and this is in most cases the only structural feature discernible. These planes, which evidence intense and long continued pressure, are inclined usually at very high angles, the strike corresponding in direction with the line of outcrop of neighbouring intrusive masses, while the irregular curving lines of foliation produced by the unequal resistance to pressure simulate in a most marked manner the uneven lamination resulting from original bedding. It is, therefore, not surprising that in many descriptions of exposures of similar rocks such a structure has been repeatedly mistaken for stratification, the descriptions asserting the frequent and usual highly tilted character of these rocks.

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*On the Relations and Structures of certain Granites and Associated Arkoses on Lake Timiskaming, Canada, Rep. B.A.A.S., Toronto, 1897, pp. 656-660.

†Geol. Mag., New Series, Decade IV., vol. V., No. 1, pp. 39-41, January, 1896.

Although the slaty cleavage, especially in the upper portion of this rock, occasionally corresponds with the original stratification, there is no necessary connexion between the two. The hardness of this rock varies widely, the least altered or more quartzose varieties being exceedingly hard, while those exposures in which a large amount of chlorite and other greenish decomposition products have been developed are so soft that they can be readily scratched. Both as a massive rock, and in its more imperfect forms of slaty structure, it exhibits the character of a conglomerate, carrying fragments of various irruptive material which vary in size from the smallest pebble to some boulders a foot or even more in diameter. In some localities the rock is so full of these fragments that very little of the finer interstitial matrix is apparent, while in other places only an occasional one is found. Usually the fragments are more or less perfectly rounded; often they are subangular, while in some outcrops these larger individuals present sharp and often re-entering angles. The breccia-conglomerate presents all the characteristics usually assigned to a rock resulting from the consolidation of an ordinary littoral deposit derived from the breaking down of an area of irruptive rocks of both acidic and basic composition. The wide area, however, over which the rock is distributed, the composition and outline of many of the larger individuals, as well as the frequent intimate association with large masses of diabasic and gabbroic rocks, are incompatible with such an interpretation of the manner of its formation.

It is often exceedingly difficult to distinguish between true conglomerates or those representing the solidification of extremely local shore deposits and agglomerate-breccias which may have a much more widespread distribution, but in some instances the most typical conglomerate phase, containing perfectly rounded and seemingly waterworn fragments, has been traced directly and continuously into areas in immediate conjunction with the parent masses where the contained fragments show no sign whatever of aqueous abrasion, the rock being a typical breccia. Many of the fragments, moreover, are composed of material which has probably been derived from beneath as a direct result of violent explosive action, as they cannot possibly be connected with any rock present at the surface in the region adjacent to these exposures.

The finer-grained portion, or matrix, of the least altered phase of this rock, possesses a rather typical clastic structure, although many of the fragments are often so irregular and angular in outline as to indicate clearly that they have not suffered the rounding or trituration to the extent that ordinary clastics of this kind exhibit. The rock is seen to consist mainly of granitic *débris,* the majority of the fragments being simple minerals; although coarser phases show occasional composite rock individuals. The minerals usually noticed are orthoclase, plagioclase, and more rarely microcline, embedded in a still finer-grained ground-mass of these same constituents, together with chlorite, sericite, epidote and zoisite, and occasional granules and broken crystals of zircon, sphene and apatite. Biotite and more rarely hornblende, both largely altered to chlorite, may also be sometimes distinguished, but fresh individuals belonging to these species are rather uncommon. Pyrite is a very frequent and often extremely abundant constituent, distributed through the rock in irregular grains and masses, but sometimes also in brilliant and well striated cubes. In many instances it may be noticed in various stages of its decomposition to hydrated oxide of iron or limonite. Ilmenite is likewise very often present, both in grains and crystals, usually more or less altered to leucoxene, and occasionally exhibiting the characteristic 'gridiron' form of this decomposition. Magnetite in black opaque particles and crystals is also rather commonly represented. In several instances broken fragments of crystals of tourmaline, showing the intense dichroism peculiar to this mineral, were detected. Occasionally, also, carbonate of lime is present as a secondary product of decomposition.

The quartz is usually in clear more or less rounded areas and is the ordinary granitic variety. It frequently shows, in a somewhat pronounced degree, the uneven or undulous extinction due to pressure. Some of the feldspar fragments are rather fresh and glassy, but most of the individuals show incipient alteration, consisting of a somewhat marked turbidity arising from the development in them of the various products of decomposition to which the name saussurite has been applied. Most, if not all, of the sericite present in the rock has been derived from the alteration of the feldspar, especially of the more minute fragments, many of these present in the finest ground-mass being wholly decomposed to this form of hydrous mica, together with epidote and zoisite. Fragments of feldspar showing microperthitic intergrowth are rather abundant. By far the greater proportion of the chlorite, which is almost invariably present, has resulted from the decomposition of biotite, although some may have been derived from hornblende originally present. The sericite occurs for the most part in the minute scales or matted aggregates, although occasionally in large plates which are sometimes macroscopically apparent. The mineral varies from colourless to pale yellowish-green, showing brilliant chromatic polarization between crossed nicols. The chlorite and sericite usually serve as a finer interstitial cement filling in the spaces between the quartz and feldspar grains. The epidote and zoisite occur in irregular granules and crystals, the former polarizing in brilliant colours while the latter, which is usually in more perfect crystals, shows the deep bluish or yellowish colour characteristic of this mineral between crossed nicols. As a rule composite fragments, made up of two or more minerals occupying their original positions in the rock from whose waste they were derived, are rarely seen in this finer matrix, but with a progressive increase in coarseness of grain such fragments gradually appear. As a rule, even when small, these rock-fragments possess a more rounded outline than individuals made up of simple minerals which are very frequently quite sharp and angular.

In this matrix or ground-mass just described are embedded fragments, pebbles and sometimes even boulders of biotite-granite or granitite, hornblende-granite, diabase, diorite (?) quartzite and fine-grained slaty greywacké or hälleflinta-like rock, representing an extremely fine-grained mosiac of feldspar and quartz. Many of these larger fragments, as is usual in similar squeezed rocks, are surrounded by a rim of sericite and epidote, while occasionally, where the mass has been subjected to intense pressure and pronounced pneumatolytic action, as on Ko-ko-ko bay in Timagami lake, the whole matrix has been altered to a hydromica schist infiltrated with secondary silica, while the pebbles have undergone considerable stretching and deformation. Granitite pebbles and fragments are by far the most abundant and are almost invariably present where outcrops of this rock occur. In occasional localities individuals of diabase, which are next in point of general abundance, predominate over those of granitite. The granitite is usually of a distinct flesh-red or pink, sometimes reddish-grey and occasionally greyish colour.

It is commonly rather coarse in texture and more rarely pegmatitic. Macroscopically it shows a preponderance of pinkish feldspar, a much less proportion of greyish translucent quartz and a sparing quantity of a greenish ferro-magnesian mineral. A section prepared from one of the pebbles obtained from an exposure on Gull Rock islands in Lake Timiskaming showed the rock composing it to be greatly decomposed, the feldspar turbid, filled with sericite, epidote and calcite, and the bisilicates almost entirely altered to chlorite. Orthoclase apparently predominates, but plagioclase is abundant and microcline in small quantity also occurs. The quartz is the ordinary granitic variety, full of inclusions, and while possessing a somewhat wavy extinction does not show much further evidence of having been subjected to very intense dynamic action. A few little areas of granophyre were noted. The ferro-magnesian constituents originally present were probably both biotite and hornblende, but these minerals have been so completely altered to chlorite as to mask their true optical characters. The former mineral doubtless predominated. The change to chlorite has been accompanied by the deposition of much secondary magnetite. Ilmenite is also present and is accompanied by leucoxene, while apatite is abundant.

The diabase fragments so frequently present are usually very fine-grained, although sometimes so coarsely crystalline that the ophitic structure is distinctly discernible to the unaided eye. Occasional pieces, still more coarsely crystalline and holocrystalline in structure, may represent altered gabbros or diorites, but the ferro-magnesian minerals are all decomposed to chlorite. These pebbles are identical with those described as composed of a 'greenish feldspathic rock' in earlier reports. In every case examined they were found to be much decomposed. A thin section of a fine-grained pebble, also from the Gull Rock island in Lake Timiskaming, shows the rock to have undergone great alteration, the feldspar being saussuritized and the original augite decomposed to a pale-greenish chlorite. In spite, however, of this advanced alteration, the typical ophitic structure of diabase remains. Occasionally some of the feldspar has a broad tabular habit causing the rock to approach the gabbros in structure. The irregular areas between the plagioclase laths are filled with a felted mass of pale green chlorite scales. Leucoxene, resulting from the almost complete alteration of the ilmenite originally present in the rock, is plentifully scattered through the section. Other sections examined, belonging to much coarser grained fragments, were of essentially similar composition, revealing the same advanced alteration. The laths of plagioclase, decomposed to a partially opaque grey saussuritic mass, penetrated a matted aggregate of pale-green chlorite scales representing the allotriomorphic areas of augite originally present.

The ilmenitite has wholly disappeared, to be replaced by opaque greyish masses of leucoxene, showing the characteristic skeleton forms produced by the rhombohedral parting. Pyrite, and occasionally pyrrhotite and chalcopyrite, are constituents of these diabasic fragments and pebbles.

In addition to these pebbles and fragments of granitite and diabase others representing a greatly crushed and stretched feldspathic quartzite were noticed, containing also sericite and chlorite. Occasional fragments of a rock in which plagioclase and orthoclase are porphyritically developed in a fine-grained granular quartz-feldspar groundmass were also observed. Besides these composite pebbles there are very often fragments, usually sharply angular in outline, of both feldspar and quartz, which when present alone give the rock a decidedly porphyrite appearance. Some of these pseudo-phenocrysts embedded in a dark-green chlorite groundmass were examined, the rock thus constituted representing the 'country-rock' of Wright's mine on the east side of Lake Timiskaming. Some of these individuals proved to be feldspar, chiefly plagioclase, which have a broad tabular habit well striated and very turbid owing to somewhat advanced decomposition, while others are composite fragments of some porphyritic granitic rock with the large crystals of well striated plagioclase surrounded by finely granulated quartz.

As will be seen by a reference to the accompanying map sheets, this breccia-conglomerate is of very widespread occurrence in this district. On Lake Timiskaming it rises into hills nearly five hundred feet in height, in thick, almost structureless masses, although in large and well exposed sections lines which evidently represent original bedding may be distinguished. The total volume seen cannot be much less than six hundred feet, which perhaps represents the greatest thickness attained by this rock, although the conditions under which it must have been deposited were necessarily so unstable that at no place can the basement, upon which it originally rested, be detected. The present nature of its contact with rocks which may possibly represent refused portions of this original basement shows evidence of a considerable sinking down of the mass of clastic material into the molten or plastic magma beneath, so that it is manifestly impossible to state the true total thickness of what has been regarded as the basal member of the Huronian.

This breccia-conglomerate passes upward into a dark-greenish compact rock closely related in composition with the finer grained portion or matrix of the much coarser fragmental rock beneath. The transition upwards consists mostly in a gradual loss of the larger composite fragments.

Although in certain places an occasional pebble of reddish biotite-granite may be noticed, sections of this fine-grained and compact greywacké or feldspathic sandstone show an even-grained mixture of angular and subangular fragments, composed chiefly of quartz and orthoclase, together with, usually, a small portion of plagioclase. (Plate II., Fig. 3). Microcline though sometimes present is of rarer occurrence. These pebbles are embedded in a much finer groundmass relatively insignificant in quantity, originally feldspathic, but which is now composed of a confused aggregate of minute scales of yellowish-green sericite arising from its decomposition. A large amount of chlorite is present, usually disseminated in irregular shreds and fragments, although sometimes also forming part of the finer interstitial material, while the abundance of this mineral gives the prevailing greenish tint to the rock. Epidote and zoitite are also commonly abundant, and occasionally calcite, all these representing secondary products of alteration. Pyrite, magnetite and ilmenite are also very common constituents, the last mentioned mineral usually showing somewhat advanced alteration to leucoxene. Zircon, sphene, apatite and brownish dichroic tourmaline likewise occur, but are not by any means abundantly represented.

In ascending this rock gradually becomes finer grained, at the same time developing a marked slaty structure parallel to certain colour bands which represent original bedding. This slate, or slaty greywacke as it may be called, (for in places large masses though exhibiting the colour striping are altogether devoid of any structure except that produced by jointing), varies greatly in thickness, and in occasional localities is not represented at all. The high hills found on the northeast corner of High Rock island, as well as on the west side of Cross bay and Sandy inlet, show sections over a hundred feet in thickness, although in most cases the rock does not occur in such large volume. The colours occur in alternating bands showing a gradation from one to the other; usually of different shades of green with sometimes the addition of reddish-brown and black, thus producing a very beautiful striped rock. In some instances certain beds have been broken up, forming an autoclastic rock, which, when recemented, exhibits a beautiful mosaic of irregular though angular fragments. The constituents are essentially the same as described above, differing only in their finer state of division. The fragments as a rule show little or no evidence of water-action, being irregular and sharply angular in outline, in places forming an interlocking mosaic of quartz and feldspar grains, some of which have evidently originated *in situ,* while other portions suggest considerable recrystallization which has certainly taken place in some instances.

The structure in occasional instances is that of a microgranite, but usually the clastic origin is at once brought out by the microscope. The component fragments are remarkably uniform in size and closely compacted together, with little or no finer interstitial material, while the products of decomposition such as chlorite, epidote, sericite and leucoxene are partially scattered somewhat promiscuously through the rock in the form of irregular grains and scales, while many are arranged in a more or less definite manner in irregularly curving lines or areas.

The microscope reveals at once the nature and difference in composition of the colour-bands that so frequently characterize the rock. The lighter green bands show a prevalence of quartz together with a less proportion of feldspar, the latter being either fresh or showing only incipient sericitization, while chlorite and iron ore are only sparingly represented, if at all. The darker green bands, on the other hand, show a preponderance of feldspar, much of which has undergone somewhat extensive saussuritization, which, together with chlorite, gives the prevailing darker green shade to this portion of the rock. The dark, almost black, lines or stripings are seen to be composed of an infinite number of small crystals and opaque particles of magnetite, together with a much larger proportion of ilmenite, which, despite its extensive alteration to leucoxene, retains much of its original dark colour and opacity. The reddish-brown stripes are highly feldspathic in composition and owe their colour to abundant disseminated hydrated peroxide of iron. These slates evidently in most cases represent the consolidation of what must once have been extensive beds of volcanic mud or ashes. In certain instances, as on the eastern shores of Lady Evelyn lake and on Turner lake, they merge into coarser-grained irregular banded or foliated tufaceous rocks, which occur in immediate juxtaposition with large plutonic masses, while in other cases, as on the east shore of Lake Timiskaming to the north of Wright's mine, they are interbedded with coarse volcanic breccias or agglomerates made up of diabasic and quartz-feldspathic fragments embedded in a paste composed largely of chlorite.

In ascending this rock gradually becomes much coarser in grain, finally passing into a quartzo-feldspathic sandstone, although in certain places the latter rock was occasionally met with resting directly upon and merging downward into a basement composed of red granitite. This arkose is usually rather coarse in texture, in most places showing the characters of a grit, while certain bands or portions are conglomeratic. Many of the larger fragments in the conglomeratic phase of this rock represent very distinctly rounded or waterworn pebbles, the largest of which vary from an inch to two inches in diameter. These are composed for the most part of greyish-white, translucent, often much fractured quartz, and many of them are surrounded by a thin film of oxide of iron. Occasionally some pebbles of red quartz are present, and still more rarely others representing a 'stretched' feldspathic quartzite. Besides these there are greenish, greyish and pale-brownish, usually angular, or at most subangular, fragments of an extremely fine-grained rock, seemingly identical in composition to many of the chalcedonic-like fragments embedded in the vitrophyre tuff described by the late Prof. G. H. Williams from Onaping, Ont.* Besides these there are small, often angular fragments of red and yellow jasper together with smaller pieces of both reddish and greyish feldspar. These are embedded in a matrix composed largely of yellowish-green sericite, which, on account of its relative abundance, gives the prevailing tint to the whole rock. The rock, as has been stated, represents almost altogether the consolidation of true detrital material derived from the breaking down of granite, a portion of which is represented by exposures covering an area of nearly six square miles in the vicinity of the Old Fort narrows on Lake Timiskaming, although some of the embedded fragments are rather typical of volcanic ejectamenta; thus evidencing the continuance of the explosive activity, though with much diminished violence, which characterized the earlier portion of the Huronian period. The nature and detailed description of the passage of the biotite-granite into this overlying arkose is fully discussed in the geological description of the exposures encountered on the shores of the northern part of Lake Timiskaming.

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*Annual Report, Geol. Surv. Can., vol. V. (N.S.), Part I, 1890-91, p. 74 F. Sections Nos. 35 and 42.

The least altered form of this rock is a rather coarse arkose, which upon a superficial examination bears a remarkably close resemblance to an ordinary irruptive-granite. The constituent grains, mostly angular in outline, consist of quartz, orthoclase, plagioclase and microline, somewhat closely compacted together, with a very little intervening finer feldspathic material which is undergoing decomposition to kaolin and sericite. The reddish colour is imparted to the rock as a result of the abundance of ferric hydroxide which fills not only the minute fissures but also stains the larger feldspathic individuals. Other varieties which show no great degree of alteration or attrition and assortment through aqueous agencies are distinguished macroscopically by being brownish, pale-pinkish or greyish in colour.

A rather typical specimen of the prevailing greenish variety or 'sea green quartzite' as it has been called, obtained from a point on the east side of Lake Timiskaming (Boat-field point) about half a mile east of the Hudson's Bay Co.'s old post, shows the rock under the microscope to have originally been composed of feldspar and quartz. The quartz is in clear colourless fragments, sometimes with tolerably even outlines, but usually presenting very irregular ones, and the larger fragments are often made up of several interlocking grains. The feldspar which was originally present is now almost altogether converted into pale yellowish-green sericite which gives to the rock its prevailing colour. The sericite scales are usually exceedingly minute, but occasionally their presence can be detected macroscopically. There can be little doubt that much at least of the feldspar has been altered *in situ.* This alteration of the feldspar to sericite is shown in a beautiful manner in the section. It has left very irregularly shaped cores in the centre of the feldspar individuals. The field evidence shows in the most positive manner that the rock has had a clastic origin, but the materials, which must have originated in the immediate vicinity, show but slight evidence of having been waterworn.

At the very summit, in occasional localities, (as on the west side of the north arm of Nonwakaming lake, as well as near High pond on Maple mountain to the west of Lady Evelyn lake), this reddish or greenish arkose is overlain by thick massive beds of whitish or greyish-white quartzite. This rock is made up of angular or subangular fragments of ordinary granitic quartz filled with the usual inclusions, embedded in a finer mosiac composed of quartz fragments together with sericite. It is often much shattered and sheared, the sericite present (and which is most abundant along the planes of pressure-cleavage) being the result of intense dynamic action on the feldspar originally present. This arkose, forming the topmost member of the Huronian in this district, varies greatly in thickness. In the vicinity of Lake Timiskaming hills composed of approximately horizontal strata of this rock rise to a height of five hundred feet above the lake, while to the west of Lady Evelyn lake and forming the bulk of Maple mountain the total thickness represented is nearly eleven hundred feet.

The greatest total thickness attained by the Huronian formation in this district is nearly eighteen hundred feet, made up roughly as follows:—(1.) Breccia-conglomerate 600 feet. (2.) Slates and slaty greywackés 100 feet. (3.) Quartzite grit or arkose 1,100 feet.

Diabase and Gabbro.

Massive rocks of both the diabasic and gabbro types are frequently and intimately associated with both the epiclastic and pyroclastic rocks of the Huronian. Such rocks have often, in fact, been included as part of the Huronian system, although they appear indeed to be practically contemporaneous in origin in many cases, but they should not be counted as a part of the system when its thickness is to be ascertained. These basic intrusives apparently represent the deeper seated plutonic action connected with the volcanic outbursts that gave rise to the ejectamenta which are so abundantly represented.

Many of the masses of this kind are intimately associated with, and merge gradually into, a rather typical flesh-red biotite-granite or granitite, while several of the exposures are pierced and traversed by irregular dike-like forms and masses of pegmatitic material. This gradual passage into granitite can be directly and continuously traced in a number of instances in single outcrops. The most reasonable assumption is that all three rock-species, diabase, gabbro and granitite, represent highly differentiated portions of the same magma which have solidified at temperatures corresponding with their composition.

These basic plutonic rocks characterize large areas, occurring for the most part as a series of irregular, though often somewhat rounded batholithic masses, which send off large arms or dikes to intersect the neighbouring stratified rocks. In certain localities, as on the southwest side of Round lake (Wawiagama) a little beyond the western limit of the Lake Timiskaming sheet, as well as at Beaver mountain, south of the mouth of the Montreal river, they appear to represent the consolidation of what may possibly have been intruded sheets or sills of molten material. This, however, could not be positively ascertained, as the covering of clastic rocks, if originally present, has been removed by subsequent denudation.

These rocks; in the area here considered, usually possess a medium texture, although in many instances they are so coarsely crystalline that most of the principal constituents are plainly apparent. In general they vary from greenish-grey through dark-green to almost black in colour, although in many of the coarser phases the prevalence of feldspar with a distinct flesh-red colour gives a prevailing reddish tint to the whole mass. In most places they have a massive much jointed character, and this, together with the extensive shearing action to which these rocks have been subjected, makes it exceedingly difficult to secure even a hand specimen of well shaped outline. In occasional localities, as at Manitou rock on the west side of Lake Timiskaming, the rock shows a rude columnar or basaltic structure.

Under the microscope these rocks present a remarkably uniform mineralogical composition in the several separated masses, while the specimens obtained almost invariably exhibit, in a very typical manner, the ophitic structure which belongs essentially to diabase, although in some other areas, as well as in certain portions of the same mass, it sometimes shows the holocrystalline or granitoid structure of gabbro.

The least altered variety of the rocks of this class is made up essentially, and almost wholly of plagioclase and augite, the former mineral being present in the usual idiomorphic lath-shaped individuals penetrating the allotriomorphic augite. From the extinction-angles the plagioclase is near the basic end of the series—labradorite and bytownite. The mineral is sometimes rather fresh and glassy, although frequently it shows a marked turbidity, owing to the development in it of the usual saussuritic products of decomposition, while the aguite, which when fresh is of a distinct reddish-brown colour, is as a rule partially decomposed to green trichroic hornblende. A few rather broad tabular unstriated individuals of feldspar are usually present, and may possibly represent orthoclase. Reddish-brown, strongly pleochroic boitite is found in irregular plates, but not in any excessive amount. Quartz is likewise a rather constant constituent, occurring in small clear irregular areas filling in the lesser interspaces between the feldspar and augite. The ilmenite present very often shows the characteristic 'gridiron' alteration to lucoxene. In certain instances, as at Quinn point on the east side of Lake Timiskaming, the rock has undergone considerable decomposition, the augite being completely altered to green trichroic hornblende (uralite.)

Most of this uralite is the usual compact dark-green variety, but some of it has assumed the actinolitic habit. In other localities, as on the Quinze river, the diabase has undergone still more advanced alteration, the whole rock-mass being converted into a rather typical hornblende-schist or amphibolite as a result of intense pressure. Traces of an ophitic structure still remain, showing clearly the original character of the rock, although in places this is masked by the extreme deformation to which the rock has been subjected. The process of the uralitization and decomposition of the augite is very interesting and instructive, showing first an alteration to the compact green trichroic variety of hornblende, the individuals presenting deep-coloured borders with pale interiors. This, with an increase in deformation, assumes the fibrous or actinolitic habit, which, in turn, is decomposed to chlorite, the individuals of the last-mentioned mineral retaining much of the marked pleochroism of the hornblende. Some of the plagioclase seems remarkably fresh, although the greater proportion is altered to opaque greyish masses of saussurite, the resulting epidote, zoisite and sericite being especially abundant in those portions of the rock which have yielded most to pressure. The ilmenite originally present is often almost wholly converted to a brownish sphene, which occurs in grains or aggregates scattered through the rock.

A section prepared from a specimen representative of a small mass of highly altered gabbro that protrudes through the breccia-conglomerates and slaty greywacké on the east shore of the southwest arm of Lake Timagami, shows that the rock is now composed of feldspar, quartz, pale-green fibrous chlorite, biotite and zoisite. The mutual reaction of the feldspathic and ferro-magnesian constituents has been so pronounced, and the resulting decomposition products have in many cases wandered so far from their former positions, that the original structure is to a certain extent masked. Zoisite is a very abundant constituent of the rock as an alteration product, occurring in irregular grains and crystals. Sphene is also quite abundant and has resulted from the decomposition of ilmenite originally present. Small cores of the unaltered ilmenite still remain. The biotite is of a pale-brownish colour as a result of the leaching out of a portion of its iron.

The rock composing the upper and more precipitous portion of Beaver mountain, or the 'King of the Beavers' as it is sometimes designated, is a dark greenish-grey diabase, in which the ophitic structure is visible to the naked eye. It is much sheared and broken, the planes of cleavage and jointing being plentifully coated with dark-greenish minerals belonging to the chlorite group. Under the microscope the rock is seen to be composed mainly of plagioclase and augite. The plagioclase, which from the extinction-angles is near the basic end of the series (probably bytownite), is usually pretty fresh, but some of the individuals are rather turbid, owing to the presence of decomposition products, while considerable areas are characterized by the presence of light-greenish sericite and yellowish-green epidote and zoisite resulting from the saussuritization of the feldspar substance. The augite is as a rule fresh and occurs in allotromorphic masses pierced by the laths of plagioclase. It is reddish-brown in transmitted light, a variety frequently met with in diabases, and many of the individuals are characterized by the presence of innumerable rod-like interpositions (schillerization products.) Frequently it is noticed undergoing incipient alteration to compact pale-green trichroic hornblende. A considerable quantity of reddish-brown biotite is present in irregular plates and scales. A little quartz was also noticed, while both pyrite and an opaque iron ore, probably ilmenite, are present, scattered in irregular grains throughout the section. Besides these comparatively large and irregular areas may be seen composed of a pale yellowish-green serpentinous substance, associated with secondary calcite and often dotted with strongly refracting grains and elongated fragments of epidote, the whole showing aggregate polarization. Very often these irregular masses show the characteristic net-like structure so common in serpentine derived from the decomposition of olivine, although the small residual cores still remaining in some cases have a lower double refraction than is usual in this mineral.

Besides the masses above referred to, which are so intimately associated with the clastics of the Huronian, there are also similar basic intrusives incorporated with the Laurentian gneisses and granites, which clearly do not belong to the same magma from which these latter rocks have been produced. In most cases these appear to be of earlier generation than those associated with the Huronian, although no very positive statement can be made on this point. The gneiss in immediate conjunction is often more basic and hornblendic, seemingly showing a commingling by actual fusion of the two rocks along their line of junction.

Outcrops of a uralitic diabase marking the occurrence of a small area of this rock were noticed apparently cutting and altering the granitite-gneiss exposed on the northwest shore of Expectation lake near the southwest end. The diabase is much finer grained near the junction with the gneiss. The specimen obtained showed the rock to be a medium-grained, dark-green, basic eruptive, the diabasic structure of which can be seen in the hand specimens. The microscope shows it to be a remarkably good instance of a diabase in which the bisilicates have been almost entirely decomposed, while the plagioclase remains in a comparatively fresh, unaltered condition. The minerals now present are plagioclase, hornblende and chlorite (doubtless representing augite originally present), ilmenite accompanied by leucoxene, apatite and sericite. A few of the plates of chlorite look as if they may have been derived from biotite. The plagioclase is in rather broad lath-shaped sections which interlace, giving a coarse ophitic structure to the rock. It is well striated (both albite and pericline laws being represented) possesses very uneven extinction and has evidently been subjected to a considerable degree of pressure, many of the crystals being shattered. The augite originally present is now almost entirely altered to a pale yellowish-green chlorite. It has evidently passed through an intermediate stage of alteration to hornblende, as that mineral, of a pale bluish-green colour and fibrous, in which the alteration to chlorite is so far advanced as to almost entirely obliterate the optical character of the hornblende, surrounds lighter, still more altered cores which doubtless represent the original augite. Magnetite resulting from the decomposition of the bisilicates, a little apatite, sericite and epidote occur as secondary products.

This diabase is in contact with a dark-green, fine-grained, compact, foliated rock, sprinkled with little crystals of pyrite. Under the microscope the ground-mass consists of a fine-grained mosaic of clear quartz and feldspar, through which run little strings of a brown biotite in fine brightly polarizing scales which are evidently of a secondary origin, and in places show an alteration to chlorite. Throughout this fine-grained material larger grains of quartz and feldspar (principally microcline) are distributed, which by their granulated appearance and very uneven extinction bear unmistakable evidence of the dynamic action to which the rock has been subjected. Large irregular grains of pleochroic epidote, colourless to pale yellow, frequently showing good cleavage, are abundant, as are also large clove-brown crystals of sphene. Crystals of zircon, fairly large, and frequently showing marked zonal structure, are plentiful. Some pyrite and iron ore were also observed.

Another mass of these basic eruptives that may be mentioned in this connexion is well exposed on the shores of McDiarmid lake, the southern part of Breadalbane lake and the islands and points chiefly in the central portion of Fanny lake.

The rock is dark-green, almost black in colour, weathering rusty or brownish owing to the oxidation of the large amount of pyrite finely disseminated through it. Atmospheric agencies have likewise produced a rough, though somewhat finely pitted surface, owing to the decomposition and removal chiefly of the coloured constituents, leaving a reticulated surface formed by the feldspar standing out in relief. The relations with the surrounding gneissic rocks of the Laurentian series seem to show its earlier genesis, and these foliated and much more acid rocks are rendered relatively more basic or hornblendic in the immediate vicinity of the line of junction, apparently as a result of the free interchange through actual fusion of the material of both rocks. The basic rock has usually a rather well marked foliation, which corresponds in general with the strike of the enclosing gneissic rocks. On McDiarmid lake this strike is S. 24° E., the rock being nearly if not quite vertical, while on Fanny lake the strike is N. 85° E. with a dip to the northwest of 85°.

Under the microscope this rock is seen to be a rather fresh diabase composed chiefly of plagioclase and augite. The plagioclase is unusually fresh and glassy and well striated, both albite and pericline laws being represented. It occurs for the most part in rather broad, lath-shaped crystals penetrating the irregular individuals of augite. As a result of pressure it usually exhibits a wavy extinction, is sometimes bent or curved and occasionally fractured and dislocated. The augite is of the reddish colour so often noticed in diabase and occurs in irregular polysomatic areas.* These composite individuals or masses are surrounded by a narrow rim of remarkably uniform width, composed of fibrous and radiating scales of pale-greenish chlorite, each separate scale being approximately at right angles to the outline of the unaltered portion. (See plate II., fig. 1.)

The augite is rather fresh, while the line of division between these 'reaction-rims' and the unaltered portion of the individual is very sharp and abrupt. Associated with the augite and frequently completely enclosed by it are irregular plates and scales of a reddish-brown strongly pleochroic biotite. Sometimes it is considerably bleached while occasionally it is altered to chlorite.

On the west side of Lake Timiskaming, nearly opposite Latours Mills, black, irregular, roughly weathering masses of a very basic rock may be noticed caught up in and penetrated by the associated granitite-gneisses mapped as Laurentian.

The hand-specimen examined is black in colour with glistening scales of mica abundantly developed through the mass. The weathered surface is rough and pitted, resembling a pumice-stone. Under the microscope the component minerals are seen to be hornblende, biotite plagioclase, garnet and iron ore. The hornblende is green in colour, trichroic, and occurs in large areas composed of an aggregate of small individuals. Occasionally these aggregates show a pale interior with a dark-green border surrounding the masses. It is undoubtedly secondary in origin and some of it is actinolitic, and is the most abundant mineral in the section. The biotite is rather pale in colour owing to the removal of a part of the iron, and frequently shows pleochroic halos surrounding embedded fragments of the other constituents of the rock. The plagioclase is not nearly so abundant, and is very frequently almost opaque from the inclusion of dark-brownish dust-like particles. The garnet is in irregular grains as is also the iron ore, which is probably magnetite. A somewhat rude ophitic structure can still be detected in the rock.

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*Annual Report Geol. Surv. Can., vol. III. (N.S.), 1887-88, p. 156 F.

Besides the foliated diorites that occur as integral and extremely basic portion of the prevailing Laurentian gneisses there are occasional and comparatively large irregular areas of massive diorite, which are apparently of earlier genesis than the foliated rocks with which they are associated. One of the largest of these masses noticed occurs on the southern mountains to the southwest of the west point of Maskinonge island, on Bear bay in Lake Nipissing. The mass has, roughly speaking, a diameter of a little over four hundred feet. A border of black mica-schist (probably a mica-diorite-gneiss) nearly three feet in width separates this massive basic rock from the gneiss, the foliation of the diorite gneiss curving round the outline of the mass. The whole mass is penetrated by reddish quartzo-feldspathic masses of dikes which are evidently extremely acidic portions of the same magma from which the gneisses have solidified. Fragments of the basic hornblendic rock are embedded in gneisses near the line of junction.

Under the microscope this rock is seen to be a garnetiferous granite, being composed of plagioclase, orthoclase, quartz, hornblende, an orthorhombic pyroxene and garnet with smaller quantities of sphene and iron ore. It possesses a holocrystalline structure and shows only slight evidences of pressure in the uneven extinction of the quartz and feldspar individuals. The feldspars as a rule are quite fresh. The hornblende is usually in massive irregular individuals of a green colour and strongly pleochroic. Occasional individuals show good crystallographic outline. Excellent examples of the micropoikilitic structure described by Dr. G. H. Williams* were observed. Thus certain areas of the rock are occupied by comparatively large individuals of hornblende which are crowded with irregular grains of quartz arranged without any reference to one another or to the matrix, and, which neither possess the complete independence of optical or orientation characteristic of granular structure nor the entire continuity of the separated portions of two interpenetrating crystal individuals.

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*Journal of Geology, Chicago, vol. I., No. 2.

The orthorhombic pyroxene, which is probably hypersthene, has a parallel extinction, is rather light in colour and has a feeble pleochroism, with light-yellowish to pale reddish tints. It is somewhat abundant and occurs in individuals having irregular outlines. The garnet is usually in large individuals full of irregular cracks. It is pale ruby-red in colour with characteristic high relief. The sphene is in irregular grains frequently imbedded in the hornblende. An opaque iron ore is rather abundant in the section examined.

GRANITE.

The rock to which this general name has been applied is, for the most part, a biotite-granite or granitite according to Rosenbuch's classification. As the details of the numerous exposures of this rock are to be found in connexion with the geological description of the lakes forming the series of canoe-routes which afford an access to or across these masses, it will only be necessary, in this connexion, to give a very general notice of this rock, applicable alike to most of these separate occurrences. It is of a prevailing reddish colour, rather coarsely crystalline, the principal constituents being usually readily distinguishable with the unaided eye. In some localities it presents a very massive structure, while occasionally it shows a very distinct foliated texture. In several cases, notably in the area adjoining Spawning and Young Loon bays of Lake Timagami, occurrences of this rock present a very coarse, often porphyritic variety, the phenocrysts being Carlsbad twins of orthoclase developed in a quartzo-feldspathic ground-mass rather poor in ferro-magnesian material. Orthoclase is the most abundant feldspathic constituent, although microcline and plagioclase are both present in considerable quantity, while quartz, which is as a rule proportionately less in amount than the feldspar, is of the prevailing granitic variety full of glass and other inclusions. The coloured constituent is generally biotite which has either partially or wholly been decomposed to a pale-greenish chlorite, the individuals preserving much of the original marked pleochroism of the minerals from which it has been derived. Epidote and sphene are both very abundant and frequently in such large crystals and fragments as to be macroscopically discernible.

In the midst of all the large granite areas considerable tracts are characterized by greenstone, while masses of this greenstone (diabase and gabbro) are frequently so intimately associated with the granite that separation, especially on the scale adopted on the accompanying maps, would be impossible. Dikes and masses of granite and pegmatite likewise accompany outcrops marking the large occurrences of diabase and gabbro. Although in most cases a marked and sharp contrast exists between the two types of rocks (acidic and basic), it was rather definitely ascertained that the rocks are very intimately related, and it seems quite evident that the dates of their respective intrusions are nearly synchronous, the basic types representing the first segregations of a magma which ultimately crystallized as granitite and granitite-pegmatite. On the other hand these areas of massive granitite merge into foliated granites of gneisses which are usually indistinguishable from, and sometimes co-extensive with, similar material described and mapped as Laurentian.

POST-ARCHÆAN ERUPTIVES.

Besides the huge masses of diabase and gabbro that are so intimately associated with the Laurentian and Huronian, most of which seems to be practically contemporaneous with these rocks, there are other intrusives occurring principally in the form of dikes which cut the Laurentian gneisses, and are thus very obviously of later origin. The greater number of these occurrences possess sharply defined and approximately parallel enclosing walls, although some have filled irregular cavities of the pre-existing rocks, and thus possess more ill-defined contours.

The first of these which may be mentioned was noticed on the east side of the Ottawa river between Les Erables rapids and Snake creek, the intrusive masses apparently piercing the associated granitite-gneisses. Macroscopically the specimen examined shows a very coarse-grained dark-grey rock, with a reddish tinge given by the abundant presence of a wine-coloured almandine garnet. Under the microscope the rock is evidently a very typical example of crushed and epigenized gabbro. The minerals noticed as present in the microscopic section are plagioclase, unstriated feldspar (possibly orthoclase), quartz, diallage hornblende, biotite, garnet, apatite, iron ore, pyrite, together with serpentine chlorite occurring as secondary products of decomposition. The plagioclase, which is by far the most abundant feldspar present, is much disturbed, bent and occasionally broken, while many of the surviving large individuals show in a very beautiful manner the uneven or undulous extinction due to pressure. Much of this mineral is quite fresh and glassy, although many irregular and often large spaces in the crystals are very turbid, owing to the abundant development of exceedingly numerous and minute scales of sericite and kaolin; these products of decomposition sometimes arranging themselves in plumose aggregates. The diallage, when free from impurities, show a rather faint, though perfectly distinct pleochroism, from light-greenish to pale-reddish. Many of the larger individuals are rendered almost isotropic by the interposition, along the planes of parting, of an almost infinite number of minute brownish, more or less opaque, particles. All stages in the development of these schillerization products may be noticed, from individuals that are entirely free from such impurities to others which are perfectly crowded with them. Some of the diallage shows somewhat advanced decomposition to serpentine. The brownish-green trichroic hornblende present occurs for the most part in the form of 'reaction rims,' surrounding and resulting from the alteration of the diallage. The wine-coloured garnets, which, together with the colouring of the diallage, have been developed by the percolation of heated water (epigenetic action), occur in small crystals and crystalline fragments, often forming an irregular zonal area surrounding the bisilicate material. The biotite, which is present in comparatively small quantity, is of a deep reddish-brown colour and strongly pleochroic.

On Iron island, in Lake Nipissing, the prevailing gneiss is intersected by huge irregular masses of a dark brownish-grey highly micaceous trap. The specimens secured as illustrative of one of these occurrences near the southwest point of the island show the rock to vary considerably in texture, some portions being fine-grained with a distinct approach to porphyritic structure, the biotite occurring in crystals with sharply defined hexagonal outlines; other specimens are much coarser grained, with the biotite in broad irregular flakes, and lacking the distinct porphyritic appearance of the fine-grained material. The rock weathers to a rusty brown colour, is greatly decomposed and filled with carbonates, causing it to effervesce freely with acid. The microscope shows that the principal minerals now present are biotite and garnet, with abundant iron ore, some accessory augite, a little hornblende (?) and masses of calcite, etc., which may represent in part feldspar originally present, though none are now observable. Apatite is abundant in good-sized long prismatic crystals. The section of the finer-grained portion contained no garnet, while in the coarse-grained phase of the rock this mineral is exceedingly abundant. The garnet is of a peculiar yellowish-brown colour and resembles the melanite variety, while the coarse portion of the rock might be described as composed essentially of biotite and melanite garnet with some little accessory augite and perhaps hornblende. The rock is a most remarkable one and further investigation of fresher material might prove it to be a hitherto unobserved member of the mica-peridotite family.

Another interesting and rather rare species of dike-rock was noticed on the most southerly of the Manitou islands in Lake Nipissing. Near the southern extremity of this small island dikes, as well as irregular masses of an alnoite-rock, cut the dark reddish and greenish granitite-gneiss representing the Laurentian. One of these dikes is about ten feet in width, running in a direction nearly east-and-west and intersecting the foliation of the gneiss almost at right angles.

Another occurrence showed a fissure about six inches in width filled with the same material. Murray* mentions the occurrence of intrusive masses of the same rock as seen on one of the islands in East bay opposite Callander station. The specimens of this rock consist of a fine-grained greenish groundmass in which are embedded large phenocrysts of biotite and augite, together with rounded greenish masses, which at first sight seem to resemble concretionary or pebble-like inclusions. On examination these simulate rude prismatic crystals, but only the skeleton forms remain, filled with decomposition products, chiefly calcite, and that may possibly represent olivine, originally present. In the hand-specimens the large plates of biotite and phenocrysts of augite are especially noticeable, at once suggesting its probable close affinity to the alnoite first described by Törnebohm†, in 1882, from the island of Alnö in Norway. The thin section, under the microscope, shows an exceedingly fine-grained and decomposed groundmass consisting of an intricate mixture of brightly polarizing scales of bleached biotite, chlorite spicules and crystals of hornblende (actinolite), calcite, pyrite, iron ore and leucoxene, in which are embedded larger individuals of augite and biotite, the former almost wholly converted to hornblende and calcite, although the characteristic skeleton forms remain. In this matrix are developed large though somewhât rude phenocrysts of biotite and augite. The large individuals of augite show a perceptible, though somewhat indistinct, pleochroism and are traversed with a network of cracks more or less filled with hornblende and calcite, products of its alteration and decomposition. They are as a rule surrounded by a rim of variable width composed of the usual hornblende (uralite), showing beautiful deep-bluish polarization colour between crossed nicols. The biotite is rather fresh, although some of the iron has been removed, and, as a consequence, exhibit brilliant chromatic polarization colour. The pleochroism is strong, from deep brownish-red to pale-yellow. The individuals have a hepidiomorphic outline, occurring in elongated plates and scales which show considerable optical disturbance as a result of pressure. The rock doubtless belongs to the group which includes the alnoites, monchiquites and fourchites but it is now so decomposed that its exact position cannot be determined. Closely related rocks have been described by C. H. Smyth, jr.,* from Central New York, and by Adams,† from Ste. Anne de Bellevue, Quebec, and from a point on the road between Ashcroft and Savona, British Columbia, three miles east of Eight-mile creek.

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*Report of Progress, Geol. Surv. Can., 1853-56, p. 122.

†A. E. Törnebohm : Melilit basalt från Alnö, Geol. Foren. I Stolkholm Förh. 1882, p. 240.

About five chains north of the last occurrence of this rock, on the west side of the same small island, beds of pink crystalline limestone occur containing more or less epidote, biotite and hornblende as impurities. The strike of the rock is about N. 80° E., while the dip is at an angle of 65°. A dike varying in width from nine and a half to eleven inches, of fine-grained, dark-greenish, almost black rock was noticed intersecting this limestone in a direction N. 4° W.

Under the microscope the rock is seen to be greatly altered, consisting chiefly of microcline and hornblende, the latter evidently secondary in origin. The original rock, unaltered, was probably an augite-microcline one and thus allied to the vogesites. The hornblende occurs in elongated pale yellowish-green individuals considerably altered to chlorite and frequently forming sheaf-like bundles of crystals. A close study of the section reveals numerous examples of comparatively unaltered cores of the original augite. The feldspar of the rock giving generally elongated sections appears to be principally microcline, although some plagioclase was also observed. It is turbid, being full of inclusions of hornblende, sericite, etc. Brilliantly polarizing secondary epidote is abundantly distributed throughout the rock.

On one of the smaller of the Goose islands, at the extreme west end of the group, the pinkish granite-gneiss strikes N. 70° E., with a dip to the south < 50°. Near the northwest end a greenish dike of fine-grained material about one and a quarter feet in width cuts across the whole end of the island running in a direction N. 58° E.

About three miles and a half northeast of Bonfield station (formerly Callander) a rock-cutting made during the construction of the Canadian Pacific railway shows a good section of a massive granitoid gneiss pierced by several dikes of a rusty-weathering medium-textured diabase. The rock has a marked concretionary structure, which is revealed as a result of ordinary weathering, the successive thin concentric layers of rock peeling off much like the coats of an onion. The dikes cut across the indistinct foliation of the associated gneissic rocks. Near the walls the dikes are very much decomposed and schistose, while the gneiss is baked and altered to a slight degree in the immediate vicinity. The largest of the dikes, near the southwest end of the cut, is six feet across with a branching arm about two feet in width. Another dike near the northeast end of the outcrop is four feet in width, while the third is only about one foot in width. The rock composing these intrusions is readily attacked by atmospheric agencies and is more or less hollowed out in the adjacent hard gneiss. Dikes and masses of precisely similar material are exposed along the line of railway between Sudbury and the Murray mine, which in a thin section under the microscope is found to be a rather typical and fresh olivine-diabase. No petrographical examination was, however, made of the rock from the locality above described, as the specimens secured were lost in transit.

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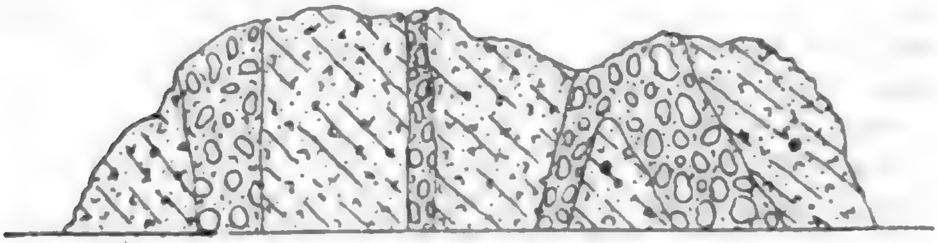
*American Journal of Science, April, 1892, August, 1893, and October, 1896.

†Ibid., April, 1882; also Annual Report, Geol. Surv. Can., vol. VII. (N.S.), p. 388 B, No. 79 A.

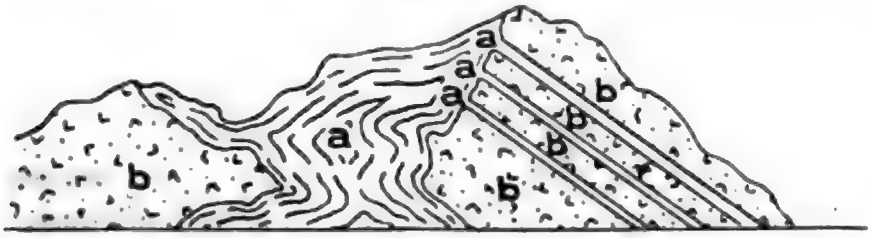
Fig. 2.



DIKES OF CONCRETIONARY DIABASE 3½ MILES N. E. OF BONFIELD.

Along the line of the northern division of the Grand Trunk railway, in the vicinity of Callander station to the east of Lake Nipissing, the various rock-cuttings show good exposures of a massive granitite-gneiss. As a rule, this is a medium-grained distinctly foliated granitic rock, in which the dark-coloured irregular strings and layers composed of the ferromagnesian constituents, (principally biotite), alternate with broader reddish bands of coarse-grained feldspar and quartz, in which lie little patches and strings of the darker material. Frequently the gneiss has a very distinct augen structure, the lenticles composed almost wholly of reddish feldspar being sometimes as much as six inches in length by two or three in breadth. The strike of the rock varies from N. 20° W. to N. 20° E. with a prevailing dip to the east at a high angle, usually over 60°. In some instances the rock is quite massive, showing little or no evidence of foliation. These reddish granitoid rocks are intersected in several places, almost at right angles to the foliation, by irregular often branching dikes of comparatively fine-grained dark greenish-grey, sometimes almost black, rocks. In the immediate vicinity of the line of contact the gneiss exhibits a narrow selvage of much finer grained rock showing the intrusive action of the dike, while in some instances fragments of the gneiss have been caught up and incorporated in the body of the dike. At the first cutting, about a quarter of a mile south of Callander, the rock is very massive and granitoid, but at the second a well marked foliation has been developed, running N. 10° W. with an easterly dip at a high angle. This rock is intersected by two dikes, dark-green to almost black in colour, containing porphyritically embedded individuals of a black, bright, glistening mineral. The walls of the dikes are more or less irregular, often serrated and frequently presenting re-entering angles of fine-grained material which penetrates the mass of the neighbouring granitic rock. At the widest places the larger of the two dikes is about seven feet thick, while the smaller is about two feet. The dike interrupts the foliation of the gneiss and near the contact both rocks are much finer in texture, while fragments of the gneiss are embedded in the dark-greenish rock. Under the microscope the rock possesses a peculiar irregular granular structure, and the intergrowth of hornblende and feldspar gives to the section a pseudo-granophyric appearance. The section is filled with a dense mass of little shreds of hornblende in a groundmass composed chiefly of broad plates of orthoclase. There are numerous large phenocrysts having centres composed of a pale-green diopsede-like pyroxene, altered on the outside to a green hornblende. Biotite is also plentiful in large fresh irregular plates full of inclusions. Titanite and apatite also occur. The whole section is sprinkled with iron ore, pyrite and granules of epidote. It is a very basic rock, near the syenite end of the peridotites and between these and the vogesites. It might be termed a hornblende-augite-minette.

Fig. 3.



West side of cutting, one mile south of Callander, G.T.R.

SKETCH SHOWING DIKE-LIKE FORMS OF MICA-PHONOLITE (a) CUTTING GRANITE-GNEISS (b).

The next cutting, situated about a mile south of Callander, runs through a hill of a deep-reddish granitite-gneiss. At the north end of the cutting the foliation is quite distinct, this structural feature striking about N. 10° E. with an easterly dip $< 60°$, but towards the middle of the cutting the rock is very massive, showing only indistinct foliation. This rock is pierced by irregular dike-like forms of a massive, dark, greenish-grey rock, which shows a marked difference in texture, being fine-grained near the containing walls of the dike and coarser toward the middle. There is a selvage of about an inch of fine-grained granitite near the contact with the darker rock. In some places these dikes have comparatively regular and straight walls, while in others they are of somewhat irregular outline. On the west side of the track near the north end three of the narrower dikes, in approximately parallel position, cut the granitite and are connected with the larger and more irregular body of the dike. The whole section exposed is a little over a hundred feet in length. The finer grained portion of the dike near the walls, shows a very compact dark-green slaty rock filled with a multitude of joints, causing the rock to break into a large number of small, irregular rhombohedral fragments. Under the microscope it is seen to be much altered and very fine-grained. It is composed of a groundmass made up of a colourless isotropic substance, sprinkled all through with irregular patches and spots (micropoikilitic) of a mineral with higher refraction and very high double refraction which may be calcite, also occasional laths of a low double refractive mineral suggesting feldspar. The section is also spotted with minute scales of green biotite. Augite, some of which is fresh, is present; but one phenocryst with inclusions of feldspar was noticed decomposed to a serpentinous product. Considerable quantities of titanite, some ilmenite, leucoxene, pyrite, apatite, zircon, fluorite and lepidomelane are also present. The section represents an alkali rock, and is probably allied to the mica-phonolites.

Other dikes than these above described are also occasionally met with, but they have not been examined petrographically.

CAMBRO-SILURIAN.

The transgression of the sea far up the valley of the Ottawa during early Palæozoic times has long been a well ascertained fact, and the character, thickness and fossil remains of the numerous and extensive Palæozoic outliers have been described. The marine invasion began with the shallow-water conditions indicated by the deposition of the conglomerate and sandstones of the Potsdam, and ended—so far as evidence is afforded by the exposures of strata below Mattawa—with the Utica. This submergence must have been gradual and of great duration, the ocean reaching its greatest depth and extent in this area about the close of the Trenton period, when a comparatively rapid re-elevation of the land took place, as indicated in part by the deposition of the Utica shale, and ending with the final emergence of the whole area to conditions of dry land.

It seems probable that the depression at present occupied by the Ottawa river, which in past geological time was of much greater extent and importance, formed, during the deposition of the Cambro-Silurian, a large gulf or arm of the sea, with transverse bays or inlets extending far into the interior of the Archæan plateau of central Ontario along depressions which even then existed, and which are now occupied by the more important tributaries of the Ottawa. This arm of the sea certainly extended as far up the Ottawa as the Mattawa, and small exposures of arenaceous limestones which have escaped the forces of denudation occur at intervals in the immediate valley of the river between Pembroke and Mattawa. The comparatively deep-water conditions indicated by the deposition of these limestones, which were certainly of much greater extent and volume than at present appearing, furnishes strong presumptive evidence for believing that the sea was continuous in the form of a strait through the valley of the Mattawa river, thus connecting directly with the vast interior basin of western Ontario in which strata of similar age and character were being deposited. The Cambro-Silurian known to occur on the Manitou and Iron islands in Lake Nipissing are doubtless outliers of the belts of rocks of the same age which outcrop farther to the west and southwest.

To the north, up the main valley of the Ottawa, it is perhaps likely that the sea extended as far as the head of Lake Timiskaming and a short distance beyond, and that strata then deposited lie concealed beneath the Niagara limestones that outcrop on the shores and islands of the northern part of this lake. This seems the most satisfactory explanation that can be offered at the present time to account for the presence of numerous, often large and angular, fragments of Cambro-Silurian strata with embedded characteristic fossils that are found lying loose at intervals along the shores of the northern part of the lake, and which certainly afford no evidence of having travelled any great distance from their source.

Chazy, Birdseye and Black River Formations.

On the west side of Iron island, in Lake Nipissing, beds of chocolate-brown and yellowish-grey, coarse sandstone or grit, occasionally becoming a fine conglomerate, rest unconformably on the upturned edges of the gneissic rocks classified as Laurentian. The rock is composed of loosely compacted and rounded grains of quartz more or less abundantly coated with hydrous oxide of iron with little or no interstitial material. The lowest beds are of a brown colour, with occasional lighter spots from which the iron oxide has been removed, while higher beds are yellowish-grey, also showing lighter coloured areas. When subjected to the action of the weather curious subspherical rings suggestive of concretionary action appear on the exposed surface, but a close inspection shows no apparent difference either in composition or texture of the part where these are developed. The beds are of good thickness, but would be useless for building purposes on account of the loose and friable nature of the sandstone. Little or no calcareous matter is present, which is a rather unusual feature, as even the coarse arkose or conglomerate lying at the base of the Manitou Islands outliers contains a considerable admixture of carbonate of lime. Murray* mentions the finding of loose fragments of limestone, with characteristic Chazy fossils, that possibly overlie these sandstones, which may thus represent the basal portion of the Chazy formation.

The Manitou islands, five in number, are situated about the middle of the wide open space in the eastern part of the lake. The largest and most northerly of these islands is about a mile in length from east to west, and is known as the Great Manitou or Newmans island. The next in size and importance is the Little Manitou or McDonalds island, while the other three are so small and insignificant that they have not been separately named.

The most southerly of these islands is somewhat less than a quarter of a mile long, but only a few chains in width. On the southeast side of the island is a dark-brown arenaceous limestone, containing angular or subangular fragments and pebbles of the subjacent gneiss. This rock is of no great thickness, and passes rapidly upward into a yellowish-grey arenaceous limestone. The whole section exposed is of small extent and thickness, the beds lying in nearly, if not quite, horizontal succession. The shore is strewn with large angular blocks of the coarse-grained, yellowish-grey, arenaceous limestone, containing many weathered and waterworn fragments of obscure cephaloped-like remains. These fragments, according to Dr. H. M. Ami, who has examined them, resemble the *Eudoceras multitubulatum* (Hall) from the Trenton and Black river.

McDonalds island, or the Little Manitou, is about half a mile in length from north to south and of no great breadth. At the southwest corner is a small patch of yellowish-grey limestone, occurring in beds which have little or no inclination. The only fossil remains visible at this locality were fragments representing chiefly the siphuncles of orthoceratites, together with crinoid stems and casts of supposed worm-burrows. Small outlying patches were also noticed beneath the surface of the water.

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*Report of Progress, Geol. Surv. Can., 1853-56, p. 125.

About the middle of the island, on the west shore, the thickest exposure of the whole of these outliers is exposed. The total thickness is about thirty feet, the beds showing a gentle inclination to the west. At the base is a greenish or yellowish arenaceous limestone holding decomposed fragments and pebbles of the gneissic rocks beneath. This is overlain by a yellowish, arenaceous limestone, comparatively free from coarse fragmental material, which in turn gradually passes upward into grey limestones and shales holding numerous fossil remains. The orthoceratites are characteristic and numerous, and one specimen obtained must have belonged to an individual over six feet in length.

The following lists of fossils have been prepared by Dr. H. M. Ami from collections made by myself and my assistant, Mr. A. M. Campbell:—

Palæophyllum or *Columnaria*, imperfectly preserved.
Amplexopora, sp.
Coscinopora (?) sp.
Monotrypella quadrata, Rominger.
Pachydictya acuta, Hall.
Plectambonites (?) sp.
Zygospira recurvirostra, Hall.
Orthis tricenaria, Conrad.
Rafinesquina Cf. *R. alternata*, (Emmons).
Trochonema umbilicatum, Hall.

Small exposures of the basal conglomerate and overlying arenaceous limestone occur on the west side of the Great Manitou island, these rocks dipping south < 5°, while on the south shore, near the old wharf, is a small outcrop of arenaceous limestone dipping east at a low angle.

From these exposures the following fossils were obtained:—

Stromatocerium rugosum, Hall.
Columnaria halli, Nicholson.
Fragments of crinoidal columns not determinable.
Ptilodictya falciformis, Nicholson.
Rafinesquina Cf. *R. alternata*, (Emmons).
Zygospira recurvirostra, Hall.
Zygospira (?) sp. undet.

Lophospira bicincta, Hall.
" sp. type of *L. helicteres,* Salter.
Maclurea (?) sp. undet.
Actinoceras sp. Cf. *Actinoceras bigsbyi,* Stokes.
Endoceras, sp.
Orthoceras, sp. Probably a new species of the type of *Orthoceras rapax,* Billings. This may be referable to the genus *Cameroceras.*

Trenton.

Between Deux Rivières and Mattawa are several small comparatively flat-lying exposures of sandstones and limestones resting upon the Laurentian gneiss close to the edge of the river, that are completely covered during times of freshet. The sections exposed are of no very great thickness or extent, the beds dipping in a southerly direction at a low angle. The most important of these outliers is the one situated on the north side of the river about four miles above Deux Rivières. The basal or sandstone beds formerly furnished material for the manufacture of grindstones of an excellent quality while local lime-kilns utilized certain portions of the higher beds exposed in this escarpment.

About six miles below Mattawa two small outliers of a light-yellowish and purplish, grey-weathering arenaceous limestone are seen in the north bank of the Ottawa river, containing abundant fossils characteristic of Lower Trenton period. Besides the rock *in situ,* the beach in the vicinity of these outliers contains a large number of somewhat water-worn blocks of these fossiliferous strata.

The following list of fossils has been prepared by Dr. Ami from a collection made at this locality.

Receptaculites occidentalis, Salter.

Crinoidal fragments too imperfectly preserved for identification, but may belong to *Glyptocrinus.*

Prasopora selwyni, Nicholson, (*Prasopora lycoperdon,* Vanuxem.)
Streptalasma corniculum, Hall.
Frondose monticuliporoid (section required for identification.)
Branching form of monticuliporoid.

Obscure monticuliporoid form, probably related to *Solenopora* (Cf. *S. compacta,* Billings.)

Strophomena incurvata, Shepard.
Rafinesquina alternata, (Emmons).
Orthis, sp. Cf. *O. tricenaria,* Salter.
Orthis (Dinorthis) proavita, W. and Sch.
Zygospira recurvirostra, Hall.

Young of *Murchisonia* (possibly *Lophospira bicarinata,* Hall.)
Fragment of trilobite too imperfectly preserved for identification.

SILURIAN.

Clinton and Niagara.

The rocks of this age, exposed on the shores and islands of the northern portion of Lake Timiskaming, have been of exceptional interest to geologists ever since their discovery and description by Logan in 1845.* Geographically this outlying patch is so widely separated from any locality where rocks of similar age are now known to exist that it has been a question whether it is indicative of an area of marine submergence connected with that in which the fossiliferous strata of Hudson bay were deposited, or whether it was in some way connected with the Niagara basin to the southwest. It has been previously asserted that these rocks belong rather to the great northern trough connected with Hudson bay, of which they are probably an outlier, and the absence of all strata of Niagara age in the region bordering the lower Ottawa has served to strengthen this belief. Although in lithological character and colour the rocks of similar age exposed on Timiskaming exhibit a marked similarity to the Niagara exposed farther to the north, the rich and varied fauna characteristic of this outlier presents no corresponding resemblance, but rather a close analogy with the Niagara formation of southwestern Ontario.

It has been shown that a pronounced similarity exists both in lithological character and fossil remains between the Niagara of the Winnipeg basin and that exposed in the vicinity of the Churchill on Hudson bay, although these areas are now widely separated, while both present organic forms that are entirely lacking in the Timiskaming outlier. These facts, therefore, seem to prove that the seas in which the Niagara sediments of the Winnipeg basin and of Hudson bay were deposited were practically continuous, while both were separated from the Timiskaming basin and the region to the southwest.

The strata forming the Timiskaming outlier occur in the form of a shallow synclinal trough, occupying somewhat more than the breadth of the lake, which is here about six miles, and extending from the northern end of Moose or Bryson island, northwestward beyond the confines of the present map. On both sides of the lake the rocks incline towards the water at varying angles, depending on the character of the shore-line; although in general the dip does not exceed 10°, and angles of lesser amount are far more common. On Mann or Burnt island, as well as on the peninsula to the north, the limestones show a very gentle westerly inclination of between one and two degrees, while on Percy island,* near the west shore, the rocks are very nearly if not quite horizontal. It is thus evident that any section made must of necessity be more or less ideal and any thickness based on the observed angles of the dip is sure to be misleading. The whole thickness exposed in any one section is somewhat less than 150 feet, and it seems certain that the total amount of the Niagara exposed on this lake cannot be greater than 300 feet, and may be considerably less. The occurrence of loose angular fragments and slabs of greyish dolomite, resembling that exposed in the vicinity of Lake Huron and Nipissing, and containing characteristic Trenton fossils, has been noticed.† These are distributed at several points on the shores of the lake and specimens were collected from the northeast shore of Chief island. Although their source has not yet been ascertained the angular character of the fragments and their abundance shows clearly that this cannot be far distant. The lake is here over 200 feet in depth and it is just possible that below the Niagara limestone and concealed beneath the waters of the lake there exists an area of Cambro-Silurian rocks. This, however, can only be ascertained by boring, as no exposures of these rocks were encountered, although a diligent search was made with this object in view.

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*Report of Progress, Geol. Surv. Can., 1845-46, pp. 69-70. Geology of Canada (1863), pp. 334-336.

†Geology of Canada (1863), p. 334.

The relatively smaller quantity of conglomerates and sandstones, characteristic shallow water deposits, and the rapid alteration from these coarser clastics to the fine-grained limestones indicative of deep water deposition, point to a rather sudden marine invasion; while the comparatively great volume of strata remaining shows a prolonged submergence. The fine-grained character of most of the limestones show that their deposition took place in a quiet arm or extension of the sea not affected by the open ocean, while the abundance and character of the fossil remains are ample testimony of the genial character of its waters.

As exposed on the west side of Wabis bay, in the northwest corner of the lake, the lower portion of this formation is composed of a loosely coherent sandstone or grit alternating with timber beds of a fine conglomerate, with pebbles chiefly of Huronian quartzite, most of which have a thin coating of yellowish or brownish iron oxide, while the matrix, consisting of similar material in a finer state of

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*So called in honour of Captain Walter Percy of the steamer *Meteor* plying on this lake.

†Geology of Canada (1863), p. 335.

division, contains a slight admixture of calcareous matter. The actual contact between this and the underlying slate of the Huronian is not seen ,although only a few yards intervene between the exposures of the two rocks. The existing relations can, however, be made out pretty clearly, for while the compact and rather massive slaty rock which here represents the Huronian occurs in exposures with more or less rounded or hummocky outlines, the arenaceous strata of the Niagara dip off or away from these hillocks at an angle of 5°.

At Haileybury, on the western shore of the lake, close to the water's edge and cropping out from the shingle, is a small exposure of light-yellow fine-grained limestone, without visible fossil remains, dipping northeast 25°. The discovery of limestone, with the general contour of the country in its vicinity, seems to suggest that a small patch of Niagara extends northerly along this shore towards Wabi bay, being perhaps three miles in length by about a quarter of a mile in breadth, underlying the clay which here effectually conceals any rocks which may be beneath.

Farther south, on Percy island, which is only a few chains in length and is separated from the western mainland by a very shallow and narrow channel, the rock exposed is a light-yellowish limestone, presenting a very uneven or cavernous surface as a result of unequal weathering. The strata are nearly if not quite horizontal, and weather from yellow to brown or almost black as a result of the iron present. Shells of various species of brachiopods are somewhat numerous. A number of the fossil remains collected have been determined by Dr. Ami as follows:—

Clathrodictyon fastigiatum, Nicholson.
Favosites gothlandica, Lamarck.
Syringopora verticillata, Goldfuss.
Crinoidal fragments.
Leptœna rhomboidalis, Wilckens.
Atrypa reticularis, Linnæus.
Meristella, sp.
Anoplotheca hemispherica, Sowerby.
Pterinea, sp.
Also branches of obscure Monticuliporidæ.

This fauna represents the Clinton, or base of the Niagara, or lower part of the Silurian.

The northern and western points of Chief island rise into comparatively high ridges of massive quartzose sandstone or quartzite-grit which present the usual rounded and glaciated outlines. Sheltered in the bay intervening between these two points is a small patch of boulder conglomerate, composed of sub-angular masses derived from the underlying quartzite. These are embedded in a calcareo-arenaceous matrix composed chiefly of pebbles and finer material, the whole representing evidently a boulder-strewn beach covered by later sediments of the Niagara formation. The surface of the quartzite on which this conglomerate rests presents the hummocky character so common in the case of the hard Archæan strata, the irregular cracks and depressions being filled by the conglomerate. Subsequent glaciation has removed much of the material, so that the exposure now presents a plane surface with a more or less net-like structure, the framework being presented by the finer arenaceous cement, while the meshes or interstices are occupied by truncated sections of quartzite boulders, as well as of the rounded hillocks of the solid rock beneath. Some of the boulders present in this conglomerate were evidently large concretions, as they exhibit concentric structure and weather very rusty owing to the disintegration of the large proportion of iron present. The finer cementing material, while relatively much smaller in amount than the pebbles and boulders, is always of a greenish or yellowish colour and frequently contains corals and orthoceratites. The action of the weather has partially obliterated the glacial striæ on this finer matrix but the sections of the quartzite boulders and hummocks exhibit these markings in great perfection.

On the southwestern shore of Chief island is another small patch of a finer grained conglomerate, the pebbles of quartzite being less numerous and of much smaller size, while the matrix contains much more calcareous matter. The rock dips southeast < 5°.

A number of rather badly preserved fossils were secured at this locality, which have been named as follows by Dr. Ami:—

Halysites catenularia, Linnæus.
Columnaria, sp., with very irregularly disposed horizontal tabulæ.
Zaphrentis, sp.
Streptelasma or *Caninia,* sp.
Rhynchonella, sp.
Murchisonia, two species.
Euomphalus, very large species.
Discosorus, Cf. *D. conoideus,* Hall.

The above fauna represents the Clinton formation or lower portion of the Niagara.

On the east side of the lake, from the point south of Chief island to within less than a quarter of a mile from Piché point, the shore is occupied by a narrow fringe of the basal conglomerates and sandstones of the Niagara. The coarser beds are of the boulder conglomerates already described, representing simply a talus of angular and sub-angular fragments detached from the elevations in the immediate vicinity of the exposures, consolidated together by a finer grained arenaceous cement of a yellowish colour, in which are also embedded fragments of corals and orthoceratites.

This boulder conglomerate passes upward into a fine conglomerate, in turn replaced by a coarse grit, and becoming finally a yellowish rather friable sandstone. These beds run in long undulating curves, closely following the general outline of the underlying quartzite, with a general westerly dip at angles varying from 10° to 15°. The action of the waves has in places caused this to disintegrate very unevenly leaving a rough pitted surface. At Piché point and for some distance north the Huronian quartzite is left entirely denuded of these deposits.

In the bay to the south of Piché point, and between this and Wright's silver mine, there are two small patches of thinly bedded light-yellow arenaceous limestone dipping in a southerly or southwesterly direction $< 5°$; immediately south of Wright's mine is another small patch of similar arenaceous limestone dipping southwest $< 9°$.

On the east shore of the lake, nearly opposite Bryson island, there are two more small patches of the arenaceous limestone exposed at the shore, wrapping round the hummocks of Huronian quartzite and dipping in a southerly or southwesterly direction $< 5°$. None of these small patches of limestone contained any visible fossil remains.

On Mann island, as also on the two small islands between this and Bryson island (Oster and Brisseau islands), as well as on the high promontory separating Wabbi and Sutton bays in the northern part of the lake, are exposed the limestones and shales that represent the deep-water deposits of this period. The limestone is of a pale-yellow or cream colour, weathering whitish, and varies in thickness from a few inches up to two feet or over. Some of the beds are very fine-grained and of rather even texture, and it is possible that some parts may prove to be sufficiently uniform for use as lithographic stone. As a building stone it is of excellent quality. These limestones, on the north shore of the lake at Dawson point, dip a little south of west at an angle of between one and two degrees, rising into cliffs of over a hundred feet in height on the west side of Sutton bay, and forming a somewhat elevated rocky plateau with a gentle westerly slope, corresponding mainly with the angle of dip towards Wabi bay. The east shore of Mann island presents a somewhat similar, though much lower, escarpment, while the western shore is a gently shelving beach, which at low water reveals considerable areas of the almost horizontal limestones. Some of the beds contain a considerable proportion of silica of a cherty character, and all the fossils are more or less silicified. The action of the weather causes them to stand out in relief and often displays their minute structures perfectly. A large collection of these fossils was made along the western shore of Mann island, comprising the following forms as determined by Dr. Ami and Mr. L. M. Lambe:—

Bythotrephis (Chondrites) gracilis, Hall.
" Cf. *B. palmata*, Hall.
Clathrodictyon fastigiatum, Nicholson.
Cyathophyllum articulatum, Wahlenberg.
" *americana*, Milne-Edwards and Haime.
Favosites gothlandica, Lamarck.
Alveolites niagarensis, Rominger (non Nicholson).
Cladopora crassa, Rominger.
Syringopora verticillata, Goldfuss.
" bifurcata, *Lonsdale*.
Halysites catenularia, Linnæus.
" *compacta*, Rominger.
Lyellia affinis, Billings.
" *Americana*, Milne-Edwards and Haime.
Thysanocrinus liliiformis, Hall.
Dendrocrinus longidactylus, Hall.
Taxocrinus n. sp.
Lichenalia concentrica, Hall.
Phænopora expansa, Hall.
Trematopora sp.
Orthis (Dalmanella) elegantula, Dalman.
Orthis calligramma, Dalman.
Platystrophia biforata, var. *lynx*, Eichwald.
Strophomenoid shell, type of *Rafinesquina*.
Stropheodonta sp. (? n. sp.)
Leptæna rhomboidalis, Wahlenberg.
Atrypa reticularis, Linnæus.
" *intermedia*, Hall.
Trematospira sp.
Pentamerus oblongus, Sowerby.
Euomphalus alatus, Hisinger.
Murchisonia sp.
" *subulata*, Hall.
Discosorus conoideus Hall.
" *gracilis* ? Foord.

Orthoceras, sp.
" *sp.*. Cf. *O. virgulatum,* Hall.
Orthoceras Cf. *O. cadmus,* Billings. Cf. *O. sub-cancellatum,* Hall.
Actinoceras vertebratum, Hall. . *A. Backi,* Stokes.
Calymene niagarensis, Hall. Probably identical with *Calymene blumenbachii,* Brongniart,
Beyrichia, sp. Cf. *B. lata,* Hall.

PLEISTOCENE.

The Pleistocene history of this and adjacent regions seems to be in the main divisible into two parts. (1) That of great accumulation of snow and the production and maintenance of a confluent ice-sheet. This is believed to have been accompanied, if not caused, by a vast regional uplift, increasing in amount to the northeastward. Following this came (2) a profound submergence, during which time the ocean invaded a large portion of the Ottawa valley, forming a marine gulf rivalling in extent and depth similar encroachments made by the sea during portions of the Palæozoic. The researches already made seem to show that channels may have connected that portion of the ocean covering the St. Lawrence and Ottawa valleys with that existent in Hudson bay, while the marine invasion may have been continuous over a vast inland basin represented at present in part by the area of the Great lakes.

Taylor, Chalmers, Gilbert, Wright, Spencer and others have been at work in this and neighbouring districts connecting and correlating the beaches representing the various stages of this submergence, but it is only possible within the scope of the present report to point out in the most general way some of the important results obtained. Taylor has shown that immediately following the retirement of the great ice-sheet which marked the first part of the Pleistocene, and to which reference will shortly be made, an important strait or arm of the sea covered the Mattawa and Timiskaming valleys, while later, as the flood subsided and the ice receded from parts of the area previously held by it, most of the waters of the Great lakes emptied for a considerable time eastward into the Ottawa through the Mattawa valley. Beaches marking the successive stages in the subsidence are well exposed on the hillsides to the north and south of Lake Nipissing, especially in the vicinity of North Bay, where they were found and described by Taylor and Wright, while the valleys of both the Mattawa and Ottawa rivers present many evidences of having been occupied for a somewhat protracted interval by a stream rivalling, if not exceeding, the St. Lawrence in volume.

In the present report the existence is assumed of a vast superincumbent glacier, of which the chief gathering-ground, as indicated by existing striæ and distribution of drift material, was situated directly over the watershed between Hudson bay and the St. Lawrence river. This hypothesis appears to offer the most satisfactory and comprehensive explanation of the various phenomena, while at the same time it is one in accord with views that have already received most general recognition among the students of Pleistocene geology.

Although thus generally agreed as to the agency producing the various results encountered, a considerable diversity of opinion exists among geologists as to whether the large number of observations already made can be adequately explained on the theory of one great ice-flow with minor oscillations, or of several distinct epochs of glaciation, each with its own proper ice-mass and separated from one another by interglacial periods during which much milder climatic conditions prevailed. The information obtained from the examination of this district is not sufficient to afford a basis of argument in favour of either view. It is, however, easy to understand that while areas situated near the extreme border of the ice-sheet may have enjoyed comparatively long interglacial periods, during which the climate was of such genial character as to permit and favour the growth of a somewhat luxuriant vegetation, others, in regions farther removed to the northeast and near the centre or centres of accumulation, showed very little, if any, amelioration of temperature. The divergence in existing striæ observed throughout this district seems perfectly explicable on the theory of differing phases of one great glacier, with comparatively short intervening lapses of time during its temporary recession and subsequent re-advance.

As the position of these first-formed ice-masses would of necessity be largely determined by the position of the highest land then existent in this region, it is probable that very early in the Glacial period there were two main gathering grounds or centres of dispersion for such ice. These would be situated respectively in the area to the northwest of Lake Timiskaming, in the vicinity of the 'Great bend' of the Montreal river, and the high quartzite ridges to the west of Lady Evelyn lake, and on the high rocky hills known to exist in the vicinity of the hight-of-land to the northwest of Lake Timiskaming. It is probable that early in the ice age these local centres sent out glaciers which flowed over the lower lands and valleys to the south, and may have been the cause of some of the striae observed on the rock-surfaces exposed in the valley of the Montreal river, as well as on the shores of Lake Timiskaming. Although it is possible that all such evidences may have been so obscured in the profound general glaciation which followed as to render their recognition and correlation matters of extreme difficulty. We may suppose that glaciers of the kind above referred to, increasing under favourable conditions, eventually coalesced as parts of one great ice-sheet, of which the distributing centre may have been gradually shifted eastward towards the neighbourhood of Opasatika and Labyrinth lakes on the canoe-route to Lake Abitibi. There is likewise sufficient evidence afforded by a study of the later striations, that must have been caused by temporary re-advances in the waning ice-sheet, that this eastward shifting of the main gathering-ground must have slowly continued, while the final recession was almost directly northeast.

It is now a well ascertained fact that the motion of ice is one resulting from its plasticity, resembling substantially the movement which obtains in an extremely thick and viscid fluid when spread upon any surface and a supply of fresh material constantly added. It is, therefore, obvious that any inclination, however slight, of the underlying surface, or the interposition of natural barriers at or near the sources of supply, were in the first instances the determining causes of the general direction of the ice flow. This onward motion once imparted was continued, and depended subsequently not so much on the nature of the land surface on which the glacier reposed as upon the general slope of the upper surface of the glacier, which inclination was imparted as a result of the unequal accumulation of material at the centres of dispersion. To the north and northeast of Lake Timiskaming the various passes or valleys leading northwards across the height-of-land are a little less than 1000 feet above the sea, although the rocky elevations in the immediate neighbourhood rise in general from 200 to 500 feet higher, while some of the hills in the vicinity of Labyrinth and Opasatika lakes show an elevation of over 600 feet above the surrounding lakes. If added to the general slope thus obtained be taken the rise consequent on a differential uplift gradually increasing in a northerly direction, the resulting slope would be sufficient to compel a somewhat rapid southwesterly flow in any glacier formed in this vicinity. while in addition it is probable that an ever increasing supply of icy material to the northeast might so accelerate this onward motion that even the interposition of such formidable natural barriers as the deep gorge of Timiskaming must have been, with its steep opposing slope, only served as temporary checks.

This great ice-sheet acted as an important agent of transportation, catching up and carrying forward large quantities of clay, sand, gravel and boulders from the higher elevations on the north to fill up the various inequalities of contour existing farther south. The drift material, though varying very much in this region, is as a rule very coarse on the higher levels and on the hill-sides facing towards the south and southwest. On these higher levels the ground is very much encumbered by more or less rounded or subangular boulders which usually do not show transportation from any great distances; although by a careful comparison of the material of this drift it was ascertained that many of these loose fragments had been carried as much as fifty or sixty miles, in a direction closely corresponding with the striation marking the maximum extension of the ice-sheet over this district. Thus, loose fragments of the buff-coloured limestone with characteristic nodular cherty matter, known to occur in a patch of somewhat limited area in the vicinity of the northern part of Lake Timiskaming, were found on Marten or Crooked lake in the township of Gladman, a distance of over fifty miles from where such rock is now found in place. The distribution of these characteristic fragments, which are an especially valuable criterion of the direction of ice-flow on account of the known limited extent of this Silurian outlier, shows that the agency which affected their transportation had a direction of movement varying from S. 7° W. to S. 18° W., thus agreeing very closely with the most abundant and pronounced striæ. On Lake Nipissing the various shales and greywackés characteristic of the Huronian exposed in the area of the Lake Timiskaming map-sheet, are rather plentifully represented among the loose boulders fringing the shores.

The stratified sands and clays so abundant in the area to the north of Lake Nipissing, as well as those in the vicinity of the Veuve river, were probably deposited very rapidly from streams issuing from the margin or front of the retreating glacier, as was likewise no doubt the case with the thick and widespread deposits of stratified clay which forms such extensive flats in the region bordering the northern portion of Lake Timiskaming. The terraces characteristic of the occurrence of these clay deposits to the north of Lake Timiskaming merely serve as marks accentuating the various stages or haltings in the ice-sheet, of which the margin was buried beneath the rising waters, thus permitting and even favouring such a mode of deposition of the englacial detritus. Especially along the course of the Ottawa and Timiskaming valley the region exhibits frequent great accumulations of morainic *débris* marking the recession of the ice-lobe occupying this deep and important depression. These deposits from the drift-laden glaciers are described in some detail in the geological description covering the area immediately bordering these topographical features.

Besides the removal and transportation of boulders, gravel and other material, there is abundant evidence everywhere of considerable abrasion of the surface produced by the passage of the ice-sheet across this district. Throughout the whole area covered by the accompanying map-sheets most of the rocky elevations have been smoothed and in many cases even polished, while scratched or striated surfaces are also common. These striæ are usually long, more or less parallel scratches, varying in size from extremely fine lines which can often only be detected by very close scrutiny, to furrows several inches in depth and width. They have in general a somewhat constant direction except in the vicinity of deep and narrow valleys, where they frequently show considerable divergence from the average direction of the district. Many of these striæ consist of a series of irregular, curving and often faint scratches, as if occasioned by an uncertain or intermittent action, while some of the deeper and more pronounced furrows exhibit irregular broken cavities at intervals in their course as though produced by a "bumping" action caused by hitches in the rocky implement producing them.

Ledges and ridges which have been long exposed to the action of the weather usually reveal little or no evidence of such striation on account of the sub-aerial decay to which the rock has been subjected, while, on the contrary, rock exposures which have been but lately denuded of their overlying soil, as well as those portions of the rocky shores of the various lakes and streams exposed only between extremes of high and low water, usually exhibit such markings in great perfection. The various gneisses and granites of the Laurentian areas are so faintly marked, if at all, that the direction of the striæ can seldom be ascertained with any degree of certainty. There seems no reasonable doubt that such markings were originally present, as under the favourable conditions already mentioned they are often plainly discernible, but as a rule prolonged atmospheric decay has so acted on exposed surfaces of these rocks that their surfaces have become roughened. On the other hand, on exposures of Huronian rocks such as slate, greywacké, quartzite and especially diabase and gabbro, these glacial markings are very frequently to be observed in all their pristine freshness. In many localities, particularly in the area covered by the Lake Timiskaming sheet, there are two, three and even four sets of striæ on the same rock-surface, differing somewhat in direction, and marking, as a rule, but slight changes in the direction of the ice-flow, during successive re-advances of the ice-sheet. The correlation of such striæ is usually exceedingly difficult and unsatisfactory, as the intervening lapse of time denoted by these divergences was doubtless of comparatively short duration.

It is probable, as has been stated, that early in the ice age glaciers of the alpine type occupied the high hills of diabase and gabbro in the vicinity of the height-of-land immediately west of the canoe-route between Lac des Quinze and Abitibi, as well as on the high ridges of quartzite-grit to the west of Lady Evelyn lake, of which Maple mountain is the most prominent eminence. The striæ which have the closest correspondence with the general trend of the valley of Lake Timiskaming and the Ottawa river were possibly caused by such a local glacier, as these markings are earlier than those which trend to the east on the one hand or to the west on the other. The striæ marking the main advance of the ice-sheet in this region show a general trend of about S. 14° W., but many of the observations noted present a marked divergence from this general direction, especially those made in the vicinity of lakes and streams where these ice markings show an unfailing tendency to conform very closely to the direction of the enclosing valleys.

The earliest of these southwesterly ice markings are those which run nearly south, the direction of ice-flow showing a gradual change in the direction of successive re-advances, following temporary recessions, from a little west of south to almost directly southwest.

In the area covered by the northern and central portions of the Lake Timiskaming sheet there are many lakes whose general trend makes but a small angle with the average direction of ice-flow while their containing valleys are narrow, rocky and steep. The northern part of Timagami, Waibikaiginaising and Wakemika lakes may be cited as examples where the glacial striæ show a general direction of a little east of south, in this respect showing the marked influence of topographical outline.

In the subjoined list, which is necessarily brief and incomplete, consisting of observations made during an exploration whose primary object was to map out and report upon the various subdivisions of the Archæan rocks, an attempt has been made wherever possible to tabulate in regard to their age the various striæ observed. Where two, three, and even four sets are noted as occurring on the same rock-surface, the order in which they appear is believed to represent, with approximate accuracy, their relative ages from the oldest to the most recent.

List of Glacial Striæ.

Lake Timiskaming.

Wabis bay, west shore of, on lot 10, con. V. Buckle township	S 15° E S 45° W
Wabis bay, east shore of, on lot 2, con. I. Harris township.	S 19° E
Sutton bay, northeast shore of, on lot 8, con. V. Harris tp.	S 51° E
East shore, west of Apika creek, on lot 38, con. I. Guigues tp.	S 81° E
Chief island, east shore of	S 36° E
Chief island, north shore of	S 66° E
Chief island, west shore of	S 14° E S 48° E S 54° E
East shore, on lot 31, con. I. Guigues township	S 32° E
Piché point, south of, on lot 12, con. I. Guigues township	S 33° E S 46° E
East shore, north of Wright's mine, on lot 7, con. II. Guigues tp.	S 23° F S 43° E
Wright's mine, (Lake Timiskaming Silver mine) on lot 62, con. I. Duhamel township "Block A"	S 21° E S 31° E S 60° E
Joanne bay, east shore of, on lot 58, con. I. Duhamel township	S 28° E S 14° W
East shore, on lot 54, con. I. Duhamel township	S 26° E South
East shore, at Narrows with Bryson island on lot 44, con. I. Duhamel township	S 21° E
East shore, opposite Drunken island, on lot 31, con. I. Duhamel township	S 4° W
West shore on lot 14, con. IV. Lorraine township	S 4° W
West shore on lot 12, con. VI. Lorraine township	S 21° E
West shore on lot 11, con. VII. Lorraine township	S 12° W S 18° W
West shore, on lot 15, con. 1. Bucke township	S 18° E S 26° W
Laperrière bay, north shore of, ½ a mile east of old H. B. Co's post, on lot 7, con. II. Duhamel township	S 21° E S 6° W
Islet near east shore about 1 mile southeast of Roche McLean	S 17° W S 32° W
Roche McLean, near west shore	S 10° E
West shore opposite Roche McLean	S 4° E
West shore 1½ miles north of Montreal river	S 4° W
West shore 1½ miles south of Montreal river	S 21° E S 19° W

Quinze river.

Islet opposite North Timiskaming P.O. Near southeast shore	S 21° E S 31° E
At second rapid above Lake Timiskaming	S 50° E
On new road to Lac des Quinze, 6 miles east of First rapid on River des Quinze	S 47° E

Lake Timagami.

Northeast arm, west end of portage to Caribou lake	S 4° W S 14° W S 19° W
Northeast arm, island in south narrows, two miles west of portage to Caribou lake	S 16° W
Northeast arm, islet near south shore, ½ mile southeast of Ferguson island	S 16° W S 20° W
Northeast arm, island east of Broom island	S 14° W
Northeast arm, point on south shore ½ mile southeast of Broom island	S 9° W S 24° W
Ko-ko-ko bay, east shore of, 1½ miles south of north end	S 9° W

Ko-ko-ko bay, islet near centre, 2½ miles south of north end	S 14° W
Ko-ko-ko bay, islet near west side, 3½ miles south of north end	S 8° W
Ko-ko-ko bay, east shore of, 3¾ miles south of north end	S 6° W
Ferguson bay, east side, near southern end	S 1° E
Ferguson bay, point on west shore 1¼ miles south of Ferguson point	S 6° E S 8° W
Sandy inlet, point on southeast shore ½ mile east of Ferguson point.	S 1° E S 18° E
Sandy inlet, north east shore, near mouth of Annima-Nipissing river	S 1° E S 18° E
Whitefish bay, east shore, 1⅓ miles south of creek from Whitefish lake	S 11° E S 4° W
Whitefish bay, point on west shore ½ mile southwest of creek from Whitefish lake	S 28° E
Whitefish bay, islet in, nearly 1 mile south of creek from Whitefish lake	S 1° E S 16° E
North arm, point on west shore, ¼ mile south of Deer island.	S 9° E S 14° K
Southwest arm, island near north end of	S 19° E
Southwest arm, east shore of, 2 miles southwest of Narrows island	S 9° W S 19° W
Southwest arm, east shore of, 5 miles northwest of south end	S 4° W S 14° W
Islet 1⅛ miles southwest of Hudson's Bay Co's post	S 4° W S 11° W S 29° W
Islet 1¾ miles east of Hudson's Bay Co.'s post	S 9° W
Islet near north end of Island bay	S 1° E S 12° W S 29° W
Portage near south end of McLean peninsula	S 4° W
High Rock island, southeast shore of	S 24° W S 29° W

Cross lake.

West shore of lake, 1½ miles south of Timagami River inlet	S 5° W
North point of island, 1¾ miles south of Timagami River inlet	S 3° W
East shore of same island, 2 miles south of Timagami River inlet	S 2° E S 7° W
West shore, ½ mile north of Timagami River inlet	S 13° W
West shore, 1¼ miles south of Timagami River inlet	S 2° E S 8° W
Small island near west shore 1¾ miles north of Timagami River inlet	S 11° W S 15° W
Point on west shore 1⅞ miles north of Timagami River inlet	S 5° W

Area Southeast of Lake Timagami.

Island near southeast end of Jumping Caribou lake	S 14° W
Marten lake, southwest shore of, ½ mile northwest of north town-line of McLaren	S 20° W
Islet in Red Cedar lake, lot 6, con. VI., Thistle township	S 2° W S 12° W
Tomiko lake, northwest shore of, on lot 5, con. 1., Fell township	S 15° W
Moxam lake, northeast shore of	S 4° W S 22° W S 29° W
Expectation lake	S 22° W
Simpson lake, at outlet of	S 22° W
Simpson lake, islet near northeast end of	S 22° W
Mackenzie lake, islet near east end of	S 22° W
Mackenzie lake, east end of	S 14° W
Breadalbane lake	S 21° W
Bush lake (near headwaters of Ottertail creek)	S 30° W
Poplar lake, west shore of, on lot 2, con. 111., Gladman township	S 30° W
Kaotisinewaning lake, south shore of, in Notman township	S 7° W
Red Water lake, west side of, near ¾ mile from outlet	S 20° W

Lake Nipissing.

Goose islands	S 25° W S 30° W
Manitou islands, most easterly islet of	South
Small islands in Goulais bay	S 15° W
Goulais point	S 25° W
Small island opposite lot 3, con. C., Caldwell township	S 19° W
North shore of, on lot 7, con. C., Caldwell township	S 25° W
North shore of, on lot 11, con. C., Caldwell township	S 25° W
Point on west shore	S 30° W
Southeast shore of Bear bay, opposite Maskinongé island	S 10° W
Deer bay, south shore of (west arm)	S 20° W
North shore of, on lot 6, con. C., Springer township	S 14° W
North shore of, on lot 5, con. C., Springer township	S 12° W
North shore of, point 3½ miles east of Dukis point	S 19° W
North shore of, point 4 miles east of Dukis point	S 14° W
Clark (Sandy) island, near western end	S 30° W S 35° W
Hardwood islands, west end of	S 20° W
Island east of east end of Hardwood islands	S 25° W
South bay, east shore of	S 23° W

Lady Evelyn lake and vicinity.

Point on north side of largest island in Lady Evelyn lake, 3 miles southwest of Obisaga narrows	S 4° W
Island in Lady Evelyn lake, 3½ miles south of Obisaga narrows	S 6° W
Southwest shore Nonwakaming lake, 3 miles west of inlet	S 5° W S 21° W
Island near east shore Nonwakaming lake, about 2 miles northwest of inlet	S 3° W S 20° W
West shore Wakémika lake	S 8° E S 22° E
South shore Wakémika lake	S 3° E S 17° E
Turner lake, southeast shore of	S 10° W

Area northeast of Lake Timagami.

Net lake, east shore of, near north end	S 4° W
Loon lake, south end of	S 3° W
Ko-ko-ko lake, east shore of, ¼ mile north of outlet	S 18° W
Ko-ko-ko lake, east shore of, 2¾ miles north of outlet	S 2° E S 3° W
Tetapaga lake, north shore of, 1 mile east of outlet	S 1° W
Turtle lake, north shore of	S 1° W S 25° W

Vermilion lake.

Turtle lake, small island near north shore of	S 10° W S 15° W S 30° W S 52° W
Waibikaiginaising lake, island near east shore of, 3 miles from south end	S 6° E S 9° E S 29° E
East end of portage between Summit and Friday lake	S 8° E S 18° E
Friday lake, west shore of, 1½ miles north of outlet	S 6° E S 16° E
Bear lake, east shore of, 2 miles north of outlet	S 4° W
Island in Vermilion lake, ½ mile southwest from northeast end	S 8° W

Wicksteed (or Shabosaging) lake.

On Rocky islets, 1½ miles southwest of inlet	S 14° W S 27° W
On southeast shore, 1¼ miles southwest of inlet	S 27° W
On northwest shore, 2 miles southwest of inlet	S 24° W
On Rocky islet, 4¼ miles southwest of inlet	S 27° W
At Narrows, 2½ miles northeast of outlet	S 14° W S 24° W
On islet near west shore, 4½ miles southwest of inlet	S 24° W S 34° W
On islet near west shore of big western bay, 4 miles southwest of inlet	S 19° W S 24° W
On west shore, 1 mile northeast of outlet	S 23° W S 31° W

Annima-Nipissing lake and vicinity.

West shore of bay on route to Mountain lake	S 10° E S 2° E S 3° W
Island near centre of lake, 4 miles from north end	S 6° W S 37° W
West shore, 3½ miles from north end	S 9° W S 20° W S 29° W
Gull Rock lake, northeast shore	S 20° W
Carrying lake, south shore of	S 7° W S 20° W
Diabase lake, south shore of	S 3° W S 18° W

Rabbit lake and vicinity.

Rabbit chute on Matabitchouan river, at outlet of lake	S 1° W S 8° W
West side, ¼ mile south of Rabbit chute	S 3° W
Burnt point, on west side of south end of Outlet bay	S 3° W S 8° W S 33° W S 38° W
Southeast shore, 1 mile northeast of Rabbit point	S 13° W
Point on east shore, ¼ mile north of Rabbit point	S 2° W S 13° W S 35° W S 42° W
Island in Rabbit lake, opposite Rabbit point	S 5° W
Ross lake, south shore of	S 4° W S 22° W S 29° W
White Bear point on west shore lake	S 3° W
Island in White Bear lake, near northeast corner	S 8° W S 15° W S 40° W

Montreal river and vicinity.

South end of Mountain or Round lake	S 42° E
On islet in river, 1 mile below Mud Lake portage	S 22° E
At Fountain falls	S 17° E
Island near west shore, near north end of Sharp lake	S 40° W

ECONOMIC GEOLOGY.

Gold and Silver.

Throughout the whole of the large area coloured as Laurentian on the accompanying map-sheets very coarse aggregates of quartz and feldspar with more or less mica, known as pegmatites, are of frequent and often rather extensive occurrence. In origin they are distinctly igneous and intrusive and in many localities are dike-like, often branching and cutting across the foliation of the gneissic rocks, although in other instances they occur as coarse-grained bands or belts interfoliated with the finer grained granite-gneisses. These acid bands sometimes become finer grained and not infrequently shade imperceptibly into the mass of the gneisses with which they are associated.

Early in 1887 the town of Mattawa was startled by the report of the discovery of gold in considerable quantity in a large number of these quartzo-feldspathic masses cutting the gneissic rocks in the immediate vicinity. An examination was undertaken of these so-called gold-bearing quartz-veins, and a number of samples taken to represent nine of the principal localities were submitted to Dr. Hoffmann, Chemist and Mineralogist to the Survey, which when assayed furnished only negative results in the case of both gold and silver. The following table shows in a concise manner the results thus obtained*:—

Locality.	Description.	Gold.	Silver.
Mattawa, hill on north side Ottawa river.	Quartz and feldspar (pegmatite) large samples from five different localities.	None	None
Hill on east side Ottawa river 3 miles north of Mattawa.	Quartz and feldspar in mica schist.	None	None
3 miles west of Mattawa and ½ mile north of McCool's mill.	Quartz with a little feldspar. Large samples from three different localities.	None	None

About the same time samples from apparently segregated veins of quartz, containing more or less disseminated sulphides and cutting what has been mapped as Laurentian gneiss in the Lac des Quinze region, were obtained by Mr. C. C. Farr of Haileybury, Ont. These were sent to the Geological Survey and handed to Dr. Hoffmann whose assays showed only traces of the precious metals. The following table condensed from Dr. Hoffmann's report will show the result of his examinations and assays*:—

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* Annual Report, Geol. Surv. Can., vol. III. (N.S.). 1887-88, pp. 30-31 T. Assays Nos. 22-30.

Locality.	Description of Specimen.	Weight.	Gold per ton.	Silver per ton.
Route to Abitibi, 8 miles S. Height-of-land.	Chalcopyrite and quartz.	1½ oz.	Trace	None
R. A. Klock's limit, north shore Lac des Quinze.	Pyrite and pyrrhotite and quartz	4⅓ "	"	"
Lac des Quinze, northeast end.	Pyrite in quartz with ferric hydrate.	8 "	"	Trace

In addition to these samples of quartz, containing in some cases pyritous material, were sent to the Director of the Geological Survey, but their assays by Dr. Hoffmann did not afford any encouraging results so far as regards their gold and silver contents. These samples were from Lake Nipissing and the region adjacent and the results of their examination in the laboratory of the Survey may be referred to as follows†:—

Locality.	Description of Specimen.	Weight.	Gold per ton.	Silver per ton.
Sturgeon R. (branch of) N. of Badgerow tp.	Finely crystalline galena and chalcopyrite with a little quartz.	6¾ oz.	very distinct traces.	15·75 oz.
Small island in Lake Nipissing.	Chlorite-schist, mica-schist, gneiss and calcite with a little pyrrhotite and pyrite.	2 "		·116 "
Vein crossing inlet, W. end Lake Nipissing.	Rust-stained quartz and gneiss	8 "	none	none
Great Manitou island, Lake Nipissing.	Feldspar and quartz with molybdenite and pyrite.	¼ "	"	"
Two miles W.N.W. of North Bay.	Rust-stained quartz with pyrite.	4¼ lbs.	"	"

In the area characterized by the presence of Huronian rocks and their associated eruptives, a large quantity of whitish or greyish translucent quartz is an almost invariable accompaniment of any extended exposure of rock. This quartz is seen to represent segregations of secondary silica filling in the various cracks and fissures caused by the profound orographic movements through which these strata have passed. Sometimes this vein-quartz is in the form of lenses or eyes occupying various small gaps or openings in the rocks, these gradually increasing in size until lenticular masses of quartz of considerable dimensions are formed. In some cases these masses run for considerable distances and approximate in character to true fissure veins, although large and typical examples of such veins are exceedingly rare in this region. Both in their horizontal and vertical extensions these "gash-veins" are exceedingly irregular, and in no case noticed can any great reliance be placed on their persistence in any direction. Calcite and dolomite often occur in association with the quartz of such veins, with varying quantities of pyrite, chalcopyrite and galena; while sphalerite and hematite (micaceous iron ore), are occasional constituents. The quartz is very often more or less cavernous or cellular, owing to the oxidation and partial removal of the sulphides originally present. Where pyrite has been abundant the quartz is more or less rusty, while the various cavities are partially filled with ochreous material. On the other hand, where copper-pyrites is the more abundant, the quartz is more or less stained and coated with green and blue carbonates of copper. Occasionally the galena shows a thin coating of carbonate of lead (cerussite) where exposed to atmospheric action, and Dr. Hoffmann makes a note of its occurrence at the Macinac lead-vein on Haycock's location, east side of Lady Evelyn lake, one and a quarter miles south of the outlet.*

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*Annual Report, Geol. Surv. Can., vol. III. (N.S.), 1887-88, part T, analyses Nos. 11-13.

†Annual Report, Geol. Survey. Can., vol. II. (N.S.), part T. analysis No. 53, Vol. IV. (N.S.), 1888-89, part R, analyses Nos. 82, 84 and 86.

In origin many of these quartz veins, and especially the larger ones, are connected with the eruption of the large masses of diabase and granite that invade the stratified slaty rocks, and often they are either on the line of junction between these two rocks or occupying breaks and fissures in its immediate vicinity, produced during the eruption of these igneous rocks. Occasionally such secondary veins of quartz occur in irregular fissures in the diabase itself.

Some of the most important of such veins noticed occur on the "Mattawapiki," as the last stretch of Lady Evelyn lake before reaching the Montreal river is called. The western shore of this portion of the lake is composed of diabase that rises abruptly from the surface of the water and often from steeply sloping or perpendicular cliffs. The contact between this rock and the slates is concealed for the most part by the lake, the eastern shore being altogether composed of a very distinctly banded greenish slate, which also rises into rather important elevations, having apparently been protected to a considerable extent from denudation by the proximity of the more unyielding diabase. The contact, for a short distance, runs inland along the western shore, leaving a comparatively narrow strip composed of the slates, which are seen to have been much shattered and broken up by the intrusion of the diabase. Some considerable masses of segregated quartz were here noticed filling irregular cavities and fissures produced during the eruptions. Associated with the quartz is more or less calcite, and in this gangue were noticed galena, copper-pyrites, iron-pyrites and zinc-blende. The banded slates on the eastern shore dip in an easterly direction at an angle of about 18°, and associated with and cutting these are similar segregated masses or "gash-vein," in which galena is the prevailing constituent. The property on which these veins are situated is owned by Messrs. Klock and Haycock, and is locally known as the Haycock mine or location. A considerable amount of development work has been done, looking chiefly to testing the quality and extent of the ore-bodies, but the inaccessibility of the locality would be a sufficient hindrance to any further operations, unless the deposit should prove of an exceptionally rich character. Assays of representative samples from these and similar veins exposed in the immediate neighborhood have been made in the laboratory of the Survey, which may be summarized as follows*:—

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*Annual Report, Geol. Surv. Can., vol. IV (N.S.), 1888-89, part R, analysis No. 60.

Locality.	Description of Specimen.	Weight.	Gold pr. ton	Silver pr. ton.
W. side Lady Evelyn lake, near outlet.	Quartz with a little calcite and chalcopyrite	1 lb. 5 oz.	Traces	2·04
E. side Lady Evelyn lake, 1¼ miles S. of outlet.	Galena with a little quartz and calcite.	6 lbs. 12oz.	"	8·75 oz.
W. side Lady Evelyn lake, 1½ miles S. of outlet (north vein).	Quartz with a little chalcopyrite, galena and zinc blende	2 lbs.	None.	0·117 oz.
W. side Lady Evelyn lake, 1½ miles S. of outlet (south vein).	Quartz with chalcopyrite...	2 lbs.	"	None.
W. side outlet Lady Evelyn lake (west vein).	Quartz with calcite, dolomite, serpentine and chalcopyrite	1 lb. 12 ox.	"	"
Island at Narrows, 3 miles S. of outlet of Lady Evelyn L.	Quartz with chlorite.......	13 oz.	"	"

The Cockburn location or mine covers several small islands in Cross lake, near the inlet from Timagami lake. On these islands, several masses of segregated quartz are exposed, but these apparently have no great regularity or persistence. The largest of these so-called veins is situated on the west side of an island about a quarter of a mile in length, about half a mile southwest of Timagami river. The island is composed of a geenish-grey greywacké, slaty in structure, which has undergone considerable alteration, and sericite is rather abundantly developed, especially on the planes of cleavage. The pressure or foliation planes, which are here apparently the only structural features displayed by these rocks, have a strike N. 16° E., and an inclination eastwards< 71°. The quartz fills an irregular fissure in the slates, is about five feet in width, has a strike of N. 38° E., and an underlie towards the southwest< 45°. Galena, iron-pyrites, copper-pyrites and malachite were all noticed embedded in the quartz. Samples taken to represent the average of these were examined in the laboratory of the Survey with the following results*:—

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*Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, part R, analyses Nos. 59-64.

Locality.	Description of Specimen.	Weight.	Gold per ton.	Silver per ton.
		lb. oz.		
Island in Cross lake near outlet	Quartz with galena and chalcopyrite	1 10	none.	·175 oz.
Cross lake..	Quartz with chalcopyrite ...	9	·058 oz.	2·058 oz.
Cross lake (same loc. as last)	Quartz with galena.........	¾	trace	3.333 oz.

Mr. P. A. Ferguson of Mattawa owns three mines or locations on Lake Timagami, known respectively as A, B and C. At location A, situated on the east side of Sandy inlet in the northern part of the lake, the rock is for the most part a massive dark-green medium-textured diabase, much of which is broken up; the irregular cavities being filled with quartz and calcite, with which are associated yellow epidote and small dodecahedral crystals of red garnet. One of the veins from which considerable material had been taken was noticed near the water's edge and contains in addition to the minerals mentioned above a little iron-pyrites and copper-pyrites. The vein is very irregular and only about a foot in width and thus too small to constitute a workable deposit. At location B, situated on the north side of the northeast arm of Lake Timagami, about two miles east of the portage into Caribou lake, the rock is a pearly greyish-green sericite-schist, striking N. 68° E. and dipping northwards< 70°. Associated with this is a lenticular mass of light-grey rusty weathering dolomite, containing reticulating veins of quartz that stand out on weathered surfaces. Chiefly at the contact between these two rocks is a considerable deposit of iron-pyrites, with a little copper-pyrites and arsenopyrite (?). Location C. is on an island now known as Ferguson island, to the southwest of this point, and consists of iron-pyrites in association with sericite schists.

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*See Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, part R, analyses Nos. 54, 57 and 58.

Assays of specimens taken as representatives of these three deposits gave the following results in the laboratory of the Survey*:—

Locality.	Description of Specimen.	Weight.	Gold per ton.	Silver per ton.
Ferguson location A, Sandy inlet, L. Timagami	Quartz with little pyrite and chalcopyrite.	11 lbs.	trace	trace
Ferguson location B, north-east arm L. Timagami.	Quartz with finely disseminated pyrite.	5 lbs.	trace	.233 oz.
Ferguson location C, Is'd in N. E. arm L. Timagami. .	Rust-stained sericite schist with pyrite.	15 oz.	trace	·116 oz.

The Denedus islands near the entrance to Muddy-water bay on Lake Timagami, and so-called after a well-known member of the Timagami band of Indians, is another mining location, owned by Mr. James Holditch of Sturgeon Falls. On the two large islands composing this group the rock is a dark greenish-grey feldspathic sandstone or greywacké, sometimes slaty in structure but usually massive. The rock is much broken up in places, and the irregular cracks and cavities thus formed are filled with grey translucent quartz, with which is usually associated more or less pinkish dolomite. Occasionally these fissures are so large as to include considerable masses of quartz. On the west island a quartz vein about two feet in width occurs, with a southeasterly strike, containing both iron and copper-pyrites. A somewhat larger segregated mass of quartz occurs on the island to the east, with similarly disseminated grains and fragments of iron, and copper-pyrites and occasionally a little galena. Assays of specimens from both these islands were made in the laboratory of the Survey with the following results†:—

Locality.	Description of Specimen.	Weight.	Gold per ton.	Silver per ton.
		lbs. oz.		
Denedus islands (east vein).	Quartz with a little chlorite and dolomite.	2 6	none	none
Denedus islands (west vein).	Quartz with chlorite chalcopyrite and pyrite.	3 6	none	none

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*Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, part R, analyses Nos. 69-71.

†Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, part R, analyses Nos. 79-80.

Large masses of iron-pyrites, associated with pyrrhotite, copper, pyrites and magnetite, occur on the east side of Timagami island in Lake Timagami and on the southeast shore of Vermilion lake, to the north of the northeast arm of Lake Timagami. Samples of these were assayed for gold and silver, but with negative results in both cases. Subsequently Mr. E. V. Wright, who had located the Vermilion Lake property, had the ore assayed for nickel, but less than one per cent of this metal was found. The following statement gives the results of the assays made[*]:—

Locality.	Description of Specimen.	Weight.		Gold per ton.	Silver per ton.
		lb.	oz.		
Timagami is'd. (east shore).	Pyrite, chalcopyrite, magnetite, with chlorite......	4	2	none	none
Vermilion lake	Pyrite in chlorite-schist and quartzite.........		13	"	"

On Matthias island, about two miles northeast of the Hudson's Bay Co.'s post on Bear island in Lake Timagami, a quartz vein with a somewhat uniform width of about eight feet was noticed. The quartz is white and translucent, filled with rusty cavities and a little copper-pyrites, iron-pyrites, malachite and ankerite were noticed. Although so promising in appearance assays made in the laboratory of the Survey show neither gold nor silver.[†]

At the Guay mine, in rear of the township of Fabre, on the east side of Lake Timiskaming, according to Mr. J. Obalski of Quebec, a considerable amount of copper-pyrites has been found. This, associated with and disseminated through diabase, probably an extension eastward of the mass which reaches Lake Timiskaming at Quinn point, shows on assay according to Mr. Obalski, gold, .02 oz., and silver, 1·56 oz. per ton of 2,000 lbs.

Other specimens examined in the laboratory of the Survey during the progress of the exploration, from veins and masses of quartz that are of less importance either on account of the negative or small results obtained, or the limited extent of the masses themselves, are enumerated below*:—

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[*] Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, Part R, analyses Nos. 78 and 52.

[†] Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, Part R, analysis No. 53.

Locality.	Description of Specimen.	Weight.		Gold per ton.	Silver per ton.
		lb.	oz.		
N. end of Lake Timagami..	Pyrite in quartz and calcite (from 10 ft. vein).		7¼	Trace.	None.
Little river, 1 mile F. Lake Timiskaming.	Greyish opaque quartz with a little pyrite.	2	10	None.	„
Point E. of outlet Hay lake, N.E. arm Lake Timagami	Quartz with a little chlorite and chalcopyrite.	1	14	Trace.	290 oz.
N. shore, N.F. arm, ¾ mile W. portage, Lake Timagami.	Quartz with traces of iron and copper.	1	3	None.	None.
Montreal river, 6 miles from mouth.	Red and white quartz with a little chalcopyrite.		14	Distinct trace.	„
E. shore Ferguson bay, Lake Timagami.	Calcite with a little chlorite and chalcopyrite.	1	11	None.	„
Small islet in Whitefish bay, Lake Timagami.	Quartz with pyrite in feldspathic sandstone.	4	3	Trace.	Trace.
Islet ¾ mile W. of Timagami post.	Quartz with a little dolomite and chlorite.		6	None.	None.
Two miles N.W. of Timagami post.	Quartz with chlorite and a little pyrite.		8½	„	„
Island near S. end S.W. arm Lake Timagami.	Rust-stained quartz with a little pyrite.	1		„	„
Mountain lake, Montreal river.	Rust-stained quartz with pyrite and chalcopyrite in diabase.	1	⅓	Trace.	Trace.
Portage near S. end of Lake Timagami.	Quartz with chlorite and dolomite.	2	11	None.	None.
Island 1¼ miles N.E. Timagami post.	Rust-stained quartz with a little ilmenite.	1	7	Trace.	„

Although the results given in the above tables are not very encouraging it must be remembered that the assays were made from material obtained during the progress of an exploration over a wide stretch of country in which only limited opportunities were afforded for examination and selection, while only those quartz masses were visited which were noticed exposed at or near the shores of lakes embraced by the survey or in localities otherwise accessible. No systematic attempt has ever been made at prospecting throughout the greater portion of the district, although a few enterprising individuals have looked over part of the area in the hope of finding some unusually rich mineral deposit. A large portion of the area covered by the Huronian rocks in the northwestern part of the region is thickly covered by forest, composed chiefly of evergreens, which conceals much of the surface, rendering any attempt at prospecting difficult. The inaccessibility of the region has also generally prevented any extended examination by prospectors, but the recent survey of the Nipissing and James Bay railway, and the proposal to run this line northward from North Bay to the east end of Lake Timagami, has again drawn attention to this region as a promising mining field. The Huronian belt of rocks is the same that traverses the Sudbury mining district to the southwest, while similar associations of slate and greywacké broken through by diabase, gabbro and granitic intrusions, furnish conditions equally favourable to the presence of metalliferous sulphides or gold-bearing quartz-masses now known to exist in the vicinity of Wanapitei lake, immediately adjoining the Timiskaming sheet to the southwest.

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*Annual Report, Geol. Surv. Can., vol III. (N.S.), 1887-88, Part T, analysis No. 32.

†Annual Report, Geol. Surv. Can., vol. IV. (N.S.), 1888-89, Part R, analyses Nos. 10, 72, 73, 75, 77, 65, 67, 68, 87, 81, 66.

One of the most important of the mineral deposits in this district, both on account of its comparative accessibility and the character and size of the ore-bearing body, is what has usually been known as the Lake Timiskaming silver or lead mine (Wright's mine) comprising portions of lots 61, 62 and 63 of range I., in the township of Duhamel, in what are called Blocks A and B, on the east shore of Lake Timiskaming.

Although this deposit was brought to notice by Mr. E. V. Wright of Ottawa in 1877, the existence of ore at this place was known long before, for on a "Map of North America,"* based on D'Anville's map, and published about 1778, the small bay on which it is situated is named "Anse à la Mine."

In the vicinity of the mine the rock is the breccia-conglomerate forming the basal member of the Huronian in this district, the pebbles or fragments of which are chiefly of granite, diabase or other eruptive rocks, embedded in a greenish, chloritic, slaty matrix which owing to pressure appears to curve around or enfold the enclosed fragments.

The deposit occurs in a brecciated or shattered belt of the rock composed of angular or subangular fragments, the interstices being filled by galena with occasionally a small quantity of iron-pyrites together with more or less pink dolomite. Although this zone is about eighty feet in breadth and contains a varying quantity of galena throughout, only about six feet can be said to carry the mineral in workable quantity, and even this with considerable admixture of gangue and rocky matter. The rock immediately adjoining and enclosing the deposit has a decidedly porphyritic appearance, crystals and fragments of white feldspar and grains of transparent quartz being embedded in a fine-grained greenish matrix. Under the microscope this fine-grained groundmass is seen to be composed of finely granulated quartz and feldspar, together with a considerable quantity of chlorite and sericite in fine scales. Through this are scattered the larger fragments which are apparent to the eye. Some of these are composite fragments of some porphyritic rock, with large crystals of well striated plagioclase and finely granulated quartz. Whilst the majority of the quartz-fragments bear evidence of having been subjected to considerable pressure one large subangular grain extinguishes very evenly and shows little or no trace of disturbance. The plagioclase individuals have a broad tabular habit, are well striated, very turbid, and apparently constitute the predominant feldspar, although unstriated feldspar was observed. Ilmenite, accompanied by leucoxene, is rather plentiful; some of it is entirely altered to the latter mineral.

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*See Map No. 5, Mill's Report on Boundaries of Ontario, Toronto. 1873

Samples of the ore were sent to the Geological Survey in 1877, and Dr. B. J. Harrington states* that a specimen of the galena entirely free from gangue, gave, by scorification, silver 18·958 ounces to the ton of 2,000 lbs. Another specimen received about the same time, but containing a good deal of rocky matter, gave, silver 11·66 ounces to the ton, while a third specimen taken about fifty feet from the above gave, after careful separation of the gangue, silver 18·229 ounces to the ton. The mean of two assays by Dr. Hoffmann gave, silver 13·58 ounces to the ton with a trace of gold; by Prof. J. T. Donald, of Montreal, silver $21.17; by Dr. Baptie, of Ottawa, silver 23 ounces; by School of Mines, London, 13 oz. 14 dwt. 10 grs. per ton of 2,240 lbs. and lead 52 per cent. The percentage of silver in the galena itself was 26 oz. 7 dwt. 21 grs.

The silver content of the pure galena would, therefore, seem to vary from eighteen to twenty-four ounces to the ton of 2,000 lbs., but the large intermixture of rocky matter would considerably lessen these results. Iron-pyrites has been found intimately associated with the galena, and occasionally considerable quantities have been encountered in working the deposit. This is doubtless the source of the gold usually present in the ore.

Work was begun on this deposit in 1887, under the management and ownership of Mr. E. V. Wright, of Ottawa, but only preliminary development work was undertaken. During 1888, however, work was carried on very energetically, and a shaft was sunk to the depth of about 100 feet, while concentrating machinery was set up and it was proposed to smelt the ore on the spot. Various obstacles have stood in the way of the successful development of this mine, chief of which has always been its distance from railway communication and the consequent difficulties in shipment of ore or concentrates.

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*Report of Progress, Geol. Surv. Can., 1877-78, pp. 51-52.

For several years work went on in a rather desultory fashion, but in 1890 the Mattawa Mining and Smelting Co., of New York, took hold of the property and an extensive and costly plant for the proper handling of the ore was installed. The main shaft was increased in depth to over 100 feet, and two drifts were made to prove the extent of the deposit, while a diamond-drill boring carried to a farther depth of seventy-five feet proved the existence of the galena to a total depth of 140 feet. Operations were carried on energetically until March, 1891, when work was suspended. During the summer of 1896 work was again resumed, chiefly with a view of further testing the property, and it is hoped that the recent completion of the branch line of the Canadian Pacific railway to the foot of Lake Timiskaming may lead to continuous working. The main shaft is now sunk to a depth of nearly 200 feet, and it is reported the mineral shows no diminution in either quantity or silver content.

Nickel, Copper, Etc.

The Huronian belt of rocks, characterized by the presence of great deposits of nickelferous and cupriferous ores in the Sudbury district, runs with unbroken continuity through the Timagami and Timiskaming districts. Diabases and gabbros apparently identical in their composition and appearance are present over large areas, but so far no very large deposits of pyrrhotite and copper-pyrites have been found. On the west side of Timagami island, as well as on the southeast shore of Vermilion lake, considerable masses of these sulphides are present, but the assays made show only a very small percentage of nickel. Copper-pyrites is an almost invariable constituent of the diabasic masses and in places pyrrhotite is equally abundant, and it is highly probable that systematic prospecting may develop large deposits containing nickel and copper.

At the Guay mine, in the rear of the township of Fabre, the specimens of copper-pyrites gave, according to Mr. Obalski, 0·72 per cent of copper, and ·08 per cent of nickel.

The inaccessibility of the region, however, and the abundance of these nickel and copper bearing sulphides in close proximity to the main line of the Canadian Pacific railway, in the Sudbury mining district, many excellent deposits of which have not yet been developed, prevent any extended search in the Timagami and the Timiskaming districts.

Iron.

No deposits of iron ore of economic importance have as yet been found in this district, although both magnetite and hematite are rather abundantly distributed. Wherever noticed the quantity has been too insignificant or the associations such that the material seen could not be utilized with any degree of profit. Magnetite occurs in patches and small masses in the red granitoid-gneiss exposed in the neighbourhood of the Chute des Paresseux on the Mattawa, in the township of Olrig. On the west side of Kipawa lake, a short distance northwest of Gordon Creek outlet, a dark-grey gneiss containing a considerable proportion of magnetic iron ore occurs, and a quantity of this ore was mined and taken to the Wright mine on Lake Timiskaming for use as a flux in the smelting of the galena. The ore, however, is too lean and siliceous to be of commercial importance.

On Iron island, according to Mr. Murray,* "small masses of specular iron ore are common to most of the rock in the island, and in the crystalline limestone there is a very great display of it. For a breadth of about forty yards along the cliff on the east side the rock holds masses of the ore of various sizes, sometimes running in strings of an inch thick or upwards, elsewhere and at other times accumulating in huge lumps, some of which probably weigh over half a ton. The beach near the outcrop is strewed with masses of all sizes, from great boulders weighing several hundred pounds to small rounded pebbles not bigger than marbles. The limestone with which the iron-ore is associated is frequently cavernous, and the crevices and smaller fissures are thickly lined with crystals of blue fluorspar and red sulphate of barytes or cockscomb-spar. Crystalline limestone crops out on the opposite or west side of the island, and, judging by the strike of the north side it must correspond with that holding the iron-ore on the east. The same minerals were found disseminated through the rock and strewed upon the beach. At the extreme southwest point of the island the rock is again crystalline limestone, and a long beach running out from it to the westward is perfectly covered with boulders of specular iron-ore. Iron-ore occurs also at the southeast point of the island, although not in such great abundance and only in detached masses strewed upon the beach."

Several parties have searched rather thoroughly over this island and most, if not all, of the iron has been carried off and shipped away. The interior of the island is a veritable jungle, and the shore is lined with an almost impenetrable thicket of scrubby cedar.

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*Report of Progress, Geol. Surv. Can., 1853-56, p. 123.

Several small pits were noticed which had been sunk near the northeast corner of the island, but the amount of ore secured apparently did not warrant any further outlay of time or money, and it seems pretty certain that this ore is nowhere present in workable quantity. At the time of the writer's visit early in the spring most of the beach was submerged.

Magnetic iron-ore, interlaminated with bands of red, grey or black, siliceous, slaty rock was noticed in several localities, and in such considerable quantity as to constitute deposits of workable size, but the abundance of intermixed siliceous matter is probably such as to render them practically valueless. One of these deposits is situated on the southeastern end of a group of three islands near the eastern shore, about three miles from the southern extremity of the southwest arm of Lake Timagami. The exposure seen consisted of alternate bands of light and dark-grey quartzite, the dark bands being composed almost wholly of grains of magnetite. It is curiously contorted, but has in general a dip N. 7° E. $<$ 45°. In immediate contact with this to the south is a band of disintegrating greywacké and chlorite schist, dipping N. 9° E. $<$ 55°. This is filled with pyrite, which has evidently been the chief cause of its decomposition. The local attraction of the magnetic needle was so great at this point as to render the compass practically useless.

Near the west end of Turtle lake, to the north of the northeast arm of Lake Timagami, there is a somewhat similar deposit, consisting of alternating reddish and black bands of hematite or jaspery iron ore and magnetite, with some olive-green shale. The strike of the deposit accords with that of the sericite-schists in the immediate vicinity, being N. 74° E. with a dip northwards $<$ 70. In this neighbourhood, also, the compass was much affected.

A third locality in which magnetite in similar association occurs is on the Quinze river, on the tenth portage from Lake Timiskaming. Mr. W. McOuat thus describes the deposit: *"The portage is on the south, or left hand side of the river, running in a direction about southeast to a small lake in a narrow ravine, and is not more than a quarter of a mile long. The iron ore crosses the portage near the upper or south end. It occurs in the form of layers from the thickness of paper to about an inch, and is interlaminated with similar layers of whitish, grey and dull-red fine-grained quartzite. The iron-ore constitutes probably from a fourth to a third of the whole, and as the thickness of the whole band is about thirty feet the whole thickness of the layers of iron ore would probably not be

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*Report of Progress, Geol. Surv. Can., 1872-73, pp. 131-132.

less than eight feet. The band was traced along the strike for about a hundred yards. Magnetic oxide of iron was observed under similar conditions at several points on this portage, and on the next above, but in much smaller quantity."

Magnetic iron ore also occurs, but mixed with sulphides, on the southeast shore of Vermilion lake and on the east shore of Timagami island, in Timagami lake. Hematite (as micaceous iron ore) occurs as a rather common constituent of the many quartz veins cutting the Huronian throughout the northern part of the area, but it has nowhere been found in deposits of sufficient extent to be of economic value.

Although of no economic importance it will be of interest in this connexion to note here the presence of native iron embedded in the crevices of some specimens collected on Mr. McMeikin's farm, about four and a half miles east of Mattawa. This occurrence of native iron, to which Dr. Hoffman's attention was first drawn by Mr. R. L. Broadbent, was observed in some specimens collected as samples of perthite and amazon-stone on lot 7, con. B, of the township of Cameron. The following is a description by Dr. Hoffman:

*" The perthite, consisting of interlaminated brownish-red to reddish-brown orthoclase, and reddish-white albite, contained here and there inclusions of a greyish-black, massive, pebbly magnetite, partially altered, manganiferous magnetite, affording a dark-reddish-brown streak.

" Portions of the feldspar showed marked signs of weathering, the albite more especially being more or less kaolinized. Embedded in the kaolin, also in the dark reddish-brown limonite in immediate proximity to it, were observable numerous spherules of a steel-grey colour and metallic lustre. These spherules varied greatly in size, a few measuring as much as a millimetre in diameter, the greater number, however, being of far smaller dimensions, and many of microscopic minuteness. They were almost perfectly spherical in shape, strongly magnetic, very hard, indenting and scratching a hardened steel mortar; brittle; when pulverized emit a distinct phosphoretted odour; immersed in a solution of cupric sulphate, become coated with a film of metallic copper. They were readily attacked by hydrochloric acid with evolution of hydrogen and a strong odour of phosphine, leaving an insoluble residue consisting of light-brownish coloured spherules which on ignition become perfectly white. These spherules, which form the nuclei of the metallic-looking grains, have apparently a concretionary structure.

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*Annual Report, Geol. Surv. Can., Vol. VI. (N.S.), 1892-93, p. 23 R.

"Mr. Johnston found the metallic spherules to have a specific gravity at 15·5° C. of 7·257 and a composition as follows:—

Iron	90·45
Manganese	0·75
Nickel	trace
Sulphur Phosphorus Organic matter	undet.
Insoluble, non-metallic, residue	7·22
	98·46

"Cobalt and copper were sought for and found to be absent. He found the insoluble non-metallic residue to contain 88·77 per cent of silica, a little alumina and ferric oxide—not estimated, a very small quantity of lime and possibly some magnesia.

"This occurrence recalls to mind that observed by me in a specimen of Huronian quartzite from the north shore of St. Joseph island, Lake Huron, Ont." *

Limestone and Lime.

On Lake Timiskaming the Niagara formation so abundantly exposed on the islands and shores of its northern portion affords an unfailing supply of excellent building stone, in blocks of large dimensions if required, while its fine and even texture as well as its colour recommend it strongly for such purposes. The Anglican church at Haileybury, on the west side of Lake Timiskaming, is being wholly constructed of material procured from exposures of this limestone on the east shore of Mann island. For purposes of making quicklime the more thinly bedded fossiliferous portions seems to be most suitable as furnishing the purest and best lime with least expenditure of fuel.

The Manitou islands, in Lake Nipissing, especially McDonald or Little Manitou island, have furnished limestone which was used to advantage during the construction of the Canadian Pacific railway. An excellent lime-kiln was noticed on McDonald island, which had evidently been used extensively. To the east of Mattawa, and between this place and Deux Rivières, a good deal of lime has been manufactured for local consumption, as also near the foot of Talon lake on the Mattawa river. In the former instance the various outliers of Trenton limestone have supplied the material, while in the latter a band of crystalline limestone has been made use of by the incoming settlers. This band of limestone would furnish a very pretty serpentine marble or ophicalcite.

When calcined the deposit of marl covering the greater portion of the bottom of Emerald lake to the west of the Opimika narrows on Lake Timiskaming would furnish a nearly pure and very white lime well adapted for mortar and other purposes. For such purposes the marl should be moulded into bricks which, after drying, may be burnt in a kiln. It might also be employed for whitewashing farm and other buildings.

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*Trans. Royal Soc. Can., vol. VIII., sect. III., p. 39, 1890.

Granite and Gneiss.

During the construction of the Canadian Pacific railway the greyish evenly foliated gneissic rocks, often easily procurable in large blocks, were used for bridge-piers and culvert work with satisfactory results. Many exposures capable of yielding both gneiss and granite of excellent quality may be found at intervals along the line of railway.

On Timiskaming lake, in the vicinity of Baie des Pères, there is a very beautiful deep flesh-red granite, in which the more or less rounded outlines of the disseminated grains and fragments of greyish translucent quartz give the rock a fine conglomeratic or prophyritic aspect. It is not known, however, whether this granite can be obtained sufficiently free from joints.

Throughout the entire area the frequent and large masses of granite exposed, as well as the more massive and granitoid portion of the rocks classified as Laurentian, would furnish building stones of good quality, but only the more readily accessible localities of such rocks can be supposed to possess any importance.

Flagstones and Slates.

The better qualities of slate do not occur extensively in this region, but some portions of the strata constituting the slaty or middle member of the Huronian present very fine-grained and fissile beds which are firm and strong; although most of the specimens seen are rather thick for roofing purposes. Search might reveal some localities where suitable material occurs in sufficient abundance to be of economic importance. Many portions would, however, seem to be well adapted for flagging.

On the east side of Lake Timiskaming, between McMartin point and Latour's mills, the shore-line for several miles is formed of vertical cliffs of very evenly banded or foliated micaceous gneiss. The layers are extremely regular, fissile and of suitable thickness to yield flagstones of the very best quality and of almost any size.

Lithographic Stone.

Some of the finer-grained beds present in the Niagara outlier on Lake Timiskaming, exposed on Mann island as well as at Dawson point on the mainland to the north, exhibit portions which were thought to be suitable for lithographic purposes. Some quarrying was done on the west shore of Mann island, and lately a company with headquarters at Vankleek Hill commenced operations in the vicinity of Dawson point with a view to securing suitable material if possible. So far, however, the specimens procured are not sufficiently uniform in texture, but it is still possible that lithographic stone of economic value may be discovered. Further examination of these beds with this object seems desirable.

Feldspar.

Although this mineral is abundantly distributed as one of the most important and characteristic constituents of these crystalline rocks, only a very small proportion is found pure enough and in sufficiently large masses to be employed for industrial purposes. To be of value the deposits must be readily accessible, and must contain the mineral in large cleavable masses easily freed from other associated minerals or impurities by a rough cobbing before shipment.

There are many large pegmatite dikes close to the line of the Canadian Pacific railway throughout this district, which might be examined with a view to obtaining supplies of feldspar. Some of those near Nasbonsing station seemed to furnish abundant and very suitable material.

Feldspar is chiefly employed in the manufacture of porcelain and pottery.

Shell Marl.

Deposits of this kind are frequently found below accumulations of peat, the marl in these instances being, therefore, of not very recent formation, but in other cases it is found to be still in process of deposition, covering the bottoms of shallow ponds or lakes.

Emerald lake, about five miles west of the Opimika narrows, is at the headwaters of one of the branches of Opimika creek, which reaches Lake Timiskaming from the west immediately above the Opimika narrows. This creek and the lakes which it empties are remarkable for their clear water. Emerald lake itself is comparatively insignificant in size, being only about half a mile in length, by a quarter of a mile in greatest width at the southern end, gradually tapering towards its outlet at the northern extremity. The lake is in a small valley from eighty to one hundred feet in depth. At the southeast corner is a very shallow bay, affording entrance to a stream which is fed by a number of large cold springs that rise at the base of an amphitheatre-like gully, at the base of steep banks composed mainly of sand and gravel. The water of the bay, although so shallow, is very cold even during the hottest days of summer, while the whole bottom is covered with a deposit of shell marl of unknown depth. That this depth is considerable there is no reason to doubt, as the soundings made with long poles failed to reach the bottom of the deposit. Besides this bay the whole lake contains marl deposited on the bottom, while the pebbles and boulders near the outlet show a considerable coating of this loosely coherent, earthy carbonate of lime. The water of these springs is evidently calcareous and is found to be slightly aperient.

According to Mr. J. F. Whiteaves, who has examined the specimens of fresh water shells obtained from this locality, the species represented are *Sphærium sulcatum* (Lam.), and *Planorbis trivolvis* (Say) var. *macrostomus* (Whiteaves).

A sample of the marl examined in the laboratory of the Survey was found to have the following composition*:—

Hygroscopic water (after drying at 100° C.)	1·06	per cent.
Lime	48·32	"
Magnesia	0·04	"
Alumina	0·07	"
Ferric oxide	0·08	"
Manganous oxide	Traces	
Potassa	Traces	
Soda	Traces	
Carbonic acid	38·01	"
Sulphuric acid	0·07	"
Phosphoric acid	0·02	"
Silica, soluble	0·10	"
Insoluble mineral matter	8·62	"
Organic matter, viz.: vegetable fibre in a state of decay, and products of its decay, such as humus, humic acid, etc., and possibly a little combined water	4·79	"
	100·12	

"Assuming the whole of the lime to be present in the form of carbonate, trifling quantities of which are, however, present in other forms of combination, the amount found would correspond to 86·28 per cent of carbonate of lime. The insoluble mineral matter was found to consist of":—

Silica	6·24	per cent.
Alumina and ferric oxide	1·51	"
Lime	0·29	"
Magnesia	0·08	"
Alkalies (?)	0·50	"
Total	8·62	

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*Annual Report, Geol. Surv. Can., vol. VII. (N.S.), 1894, p. 31 R.

Marl is often used as a fertilizer, and deposits such as that exposed at Emerald lake should be of value locally for this purpose.

Grindstones and Whetstones.

Some of the material contained in portions of the beds of coarse sandstone and grit found near the base of several of the Palæozoic outliers would probably be suitable for the purpose of making grindstones. A quarry was opened many years ago on one of these arenaceous beds exposed above Deux Rivières, which furnished some excellent grindstones. Where the layers are not thick enough for this purpose they would furnish whetstones of a very fair quality. Where too hard and compact these stones answer only for a short time, when first used, soon becoming too much polished.

Portions of the very fine-grained, banded slates and greywacké's so frequently met with throughout the northern and northeastern part of the district may probably afford material suitable for hones and whetstones.

Clay for Bricks and Earthenware.

Clay suitable for the manufacture of bricks extends over a very large area in the northern part of Lake Timiskaming, from the vicinity of the combined mouths of the Montreal and Matabitchouan rivers, northwards far beyond the confiines of the present map. The bricks for the large convent and church built by the missionaries of the Oblat order at Baie des Pères were made there. In the vicinity of North Bay, and extending thence some distance beyond Verne, brick clay is readily accessible, although sometimes concealed by the presence at the surface of varying thickness of yellow sand. A brick-yard was in successful operation at North Bay for some years, and if the local demand were sufficient it would no doubt be re-opened. Some of these beds of clay might also furnish material applicable for the manufacture of coarse earthenware, but so far no clays fit for the finer kinds of pottery have been found in this region.

Mica.

Both biotite and muscovite are among the commonest constituents of the various Laurentian gneissic rocks, but although thus widely distributed their presence in this association is not of economic importance. The numerous and often large pegmatite dikes that cut these Laurentian rocks give promise, in places, of affording a supply of mica in sheets sufficiently large and in such quantities as to be available for economic purposes. The southern portion of the township of Calvin is perhaps the most important of these localities, but so far the muscovite obtained, representing the material exposed at or near the surface, has been too inferior in quality to command a price commensurate with the cost of mining. The opening up, however, of a large portion of the southeastern portion of the area of the Lake Nipissing sheet for settlement, may bring to light other masses of pegmatite producing good mica.

Asbestus.

This mineral has been found in the district. One of these localities is situated near the west shore of the "Mattawapika" on Lady Evelyn lake, on the Haycock mining location. It is also known to occur in the northeast of Baie des Pères, but the deposits thus far discovered are not very extensive.

Graphite.

This mineral, so abundant in the Laurentian area farther to the southeast, is of rather rare occurrence in the region under description, and although doubtless present as an occasional constituent of some of the gneissic rocks its presence was only noticed at one locality, where it occurs disseminated in minute grains and scales throughout the biotite-cyanite-gneiss exposed near the shores of the Ottawa in the vicinity of Les Erables rapids and Snake creek. Its presence in a rock-mass has often been referred to as evidence of its sedimentary origin, but in this instance there seems to be no doubt whatever that the rock containing it is a rather unusual phase of the biotite-gneiss, and as such is to be considered as a foliated plutonic mass.

Apatite.

This mineral, though abundant as an accessory or accidental constituent of many of the crystalline rocks occurring in this region, has not yet been found in deposits possessing any commercial value. The only locality where it was noticed in such quantity as to be recognizable without the aid of the microscope is on the property of Mr. Emery Racicot, on lot 4, con. VI., of the township of Ferris, a short distance from Nasbonsing, a flag station on the Canadian Pacific railway. A pegmatite dike is here exposed, composed chiefly of very pure and coarsely cleavable flesh-red orthoclase, with which is associated a much smaller quantity of black biotite often in large cleavable fragments. The dike is about six feet in width, has a direction a little west of north, according with the foliation of the garnetiferous hornblende-gneiss with which it is associated. The apatite occurs very sparingly, generally in small well developed prismatic crystals embedded chiefly in the biotite. Some of the crystals noticed presented the following combination of faces: ∞P. P. OP. ∞P2. Most of the crystals were too fragile on account of their long exposure to admit of their being liberated without breaking from the material in which they were enclosed. The feldspar in this and other dikes in the near vicinity is very pure, and large pieces, many pounds in weight, could be readily secured without any admixture of foreign matter.

Fluorite.

Fluorite or flour-spar is found in large cleavable masses, associated with orthoclase, microcline and perthite, in the large pegmatite dikes that cut the biotite-gneisses in the township of Cameron, about four miles and a half east of Mattawa. The fluorite is of a light-greenish colour, but, like the feldspathic constituents of these dikes, is very much stained and infiltrated with ferric hydrate, which fills the numerous cracks and fissures present in the mineral.

Molybdenite.

The presence of this mineral as an occasional constituent of quartz veins has been noticed in this district immediately surrounding Lake Nipissing. It is stated to occur in considerable quantity to the north of Talon creek, on the Mattawa river, although its presence there was not verified during the progress of the examination of the region.

Steatite.

This mineral, usually a decomposition product of basic pyroxenic or hornblendic rocks, is not very commonly met with, but specimens were obtained of tolerably pure material from the west shore of Lake Timiskaming, about four miles south of the Montreal river.

Amazon-stone and Perthite.

These two minerals are intimately associated with one another, constituting much of the feldspathic constituents of some pegmatites which cut a readily disintegrating biotite-gneiss that outcrops on lot 7, con. B, of the township of Cameron, about four miles and a half east of Mattawa. Four openings have been made of the nature of small pits or shallow trenches, extending only a few feet below the surface. The largest dike is about five feet in greatest width, running northeast and southwest. The railway line is about 200 yards to the north, while the Ottawa river passes about 500 yards to the south of the exposure. The openings were made for apatite, and work on the property was abandoned when this material was not found. The amazon-stone when fresh is of a very beautiful deep bluish-green colour, but owing to its proximity to the surface much of the material is more or less stained, and the minute crevices are filled with ochre. This defect would doubtless soon disappear in depth. Some of the material secured at the insignificant depth reached by the present workings is remarkably good, and is suitable for cutting and polishing.

The perthite, which is intimately associated with the amazon-stone at this locality, is a pale flesh-red aventurine feldspar, shown to consist of a fine interlamination or parallel intergrowth of albite and orthoclase. The alteration of the darker-coloured flesh-red orthoclase with the paler albite, and the accompanying brilliant aventurine reflections, produce a beautiful stone when cut and polished.

Cyanite.

The occurrence of this mineral *in situ* in Canada was first noticed by the writer in 1890, in a cutting on the main line of the Canadian Pacific railway, about half a mile east of Wanapitei station. Here it occurs in flattened blade-like crystals and fragments, in association with a reddish almandine garnet in a mica-diorite-gneiss. The crystals usually conform to the foliation, but sometimes they occur in groups and clusters disposed at varying angles to the schistosity. In the more basic portions of the gneiss the crystals are darker in colour, and have undergone in places rather extensive cracking and deformation as a result of pressure. In the more acid or pegmatitic portions of the rock the cyanite is much lighter in colour and occurs in stouter prisms. Fibrolite (sillimanite) also occurs in this locality, developed chiefly along certain crevices in the gneiss. It is fibrous or finely columnar in structure, and is traversed at right angles to the fibres by numerous fine cracks. Sometimes it occurs in curious irregularly radiating or plumose aggregates. The colour when fresh is of a pale bluish-grey.

During the examination of the Ottawa river above Mattawa cyanite was again noticed as a constituent of the biotite-gneiss exposed in the cuttings on the Timiskaming branch of the Canadian Pacific railway in the vicinity of Les Erables rapid and Snake creek. Here also it occurs in long, thin-bladed crystals in association with red garnet, and is in many places so abundant a constituent of the gneiss as to characterize this rock. The crystals are usually light-bluish or greenish, but some show a beautiful deep azure-blue centre with white margins.

Fossil Corals.

The particularly fine fossil corals of the Niagara outlier exposed on the shores and islands of the northern portion of Lake Timiskaming, which have undergone in most cases complete silicification, would doubtless not only command a ready, though somewhat limited, sale as specimens, but when polished would form an attractive ornamental stone for certain purposes. The west side of Mann island exhibits abundant specimens of this kind.

Springs.

The region, as a whole, is not characterized by abundant springs, although occasionally some large ones are encountered. Opimika creek, reaching Lake Timiskaming from the west immediately north of the narrows of the same name, is chiefly fed by springs, as is also Latour creek, which enters the same lake on the west side about four miles above the Old Fort narrows. Both these streams are remarkable for the coldness and clearness of their waters, and for the fine specimens of brook trout to be found in them. A fine large spring rushes down the hill immediately behind Thompson bay, below the Opimika narrows, on the east side of Lake Timiskaming, about half a mile east of the old Hudson's Bay Co.'s post. Another spring of good water flows down at the head of Les Erables rapids on the Ottawa. As the country becomes settled many new springs will be found, but the abundance of good water contained in the many lakes and streams of the region renders the presence of springs much less important, although as a rule the water in these lakes is rather warm for drinking purposes during the summer months. During a considerable portion of the summer the presence of a large number of minute greenish or yellowish particles, often so abundant as to form a scum at the surface or around the margins of the lakes, renders the water of many of them more or less unfit for drinking purposes. The waters of the springs that feed Eemerald lake, at the head of one of the branches of Opimika creek, have already been referred to. They are the only ones known to possess therapeutic qualities.

REGIONAL DESCRIPTION.

THE OTTAWA RIVER AND LAKE TIMISKAMING.

General Features.

As may be seen by a reference to the accompanying map-sheets, a considerable length of the Ottawa is included by them. From the northeast bay of Lac des Quinze where it enters the Lake Timiskaming sheet, to the mouth of the Mattawa (which for convenience has been included in the southern sheet) the distance is about 142 miles. Three large lakes occur in this distance, which may be regarded simply as expansions of the stream.

The most northern of these expansions, known as Lac des Quinze, is very irregular in outline, with several long arms or bays running in various directions, but the most direct line of communication through the lake measures about twenty-two miles. This lake is separated from Lake Timiskaming by a short stretch of water known locally as the "Quinze river," noted for its wild and dangerous rapids, and which in its eighteen miles of length falls a distance of two hundred and sixty feet. Lake Timiskaming, into which this stream empties, is sixty-seven miles long from the mouth of the Quinze to the head of the Long Sault rapids, while Seven-league lake, which commences at the foot of these rapids, adds a further length of seventeen miles. While it would thus appear that the river, strictly speaking, embraces only about thirty-eight miles of this whole distance, it may be stated that a considerable proportion of that generally included as lake should in reality be considered as portions of the river proper. A large part of these water-stretches exceeds but very little, if at all, the average width assumed by the river when not obstructed by rapids, while at several points a swift current is present, denoting a small though appreciable change of level.

Thus Seven-league lake, in its lower portion, is only about a quarter of a mile wide, while in the upper part it never exceeds half a mile. In this lake a light current can usually be detected, showing a total fall in the whole length of about a foot during the ordinary low water of summer; but during times of freshet this current is augmented, and the total fall is increased to a little over two feet.

Lake Timiskaming itself, as noted in the appendix, shows a difference in level of a foot from the head of the Long Sault rapids to the wide portion above the Old Fort narrows, while the lower portion of the lake south of the mouth of the Montreal river is quite river-like. This difference in level is maintained by three very pronounced contractions. The most northerly of these is at the Old Fort narrows, where the lake is pinched in between two bold hills of gravel, leaving a channel a little less than 800 feet wide at ordinary stages of the water. At the Opimika narrows, about thirty-five miles farther, a still more pronounced current flows through a strait which at one place is less than 200 yards in width. This current, formerly known to the old voyageurs as "La Gabrè," shows a descent of fully half a foot. At Presquîle, about a mile north of the head of the Long Sault, the third contraction occurs, and here again a considerable current may be noticed, but not so strong as at the Opimika.

The Ottawa, from the northeast bay of Lake des Quinze, has a general direction of a few degrees south of west as far as the head of Lake Timiskaming. At this point, however, it suddenly changes, and from the head of this lake, as far as the mouth of the Mattawa river, the stream flows about S. 30° E. In places there is a decided divergence from this general course, caused by local bends, which are especially characteristic of the upper portion of the river, but from Lake Timiskaming to the Mattawa the river follows an unusually uniform and deep valley, and any bends which do occur are in the nature of large curves.

The upper part of the river above Lake Timiskaming occupies a very pronounced valley, and the hills around Lac des Quinze present the usual rounded or dome-like outlines so distinctive of areas underlain by the Archæan gneissic rocks. Except on the northern portion of the lake, where they are unusually bold, ranging from 200 to 300 feet in height, the hills are as a rule low, averaging less than 100 feet. The Quinze river, which usually breaks across the strike of the enclosing rocks, occupies an original, but not very pronounced, depression. When Timiskaming is reached these conditions undergo a decided change; and the valley, especially in the lower portion, is fiord-like in aspect. From the Mountain rapid to the mouth of the Mattawa the river breaks across irregular ranges of hills, which rise very abruptly from the water to heights of from 400 to 600 feet, while the shores on either side of Seven League lake, which are as a rule bold and rocky, preserve a rather constant elevation of from 200 to 300 feet. In the construction of the Lake Timiskaming branch of the Canadian Pacific railway along the rocky eastern bank this was so steep and abrupt that it was found necessary in most instances to make large rock-cuts, the road skirting the shore.

From the mouth of the Montreal river to the Long Sault rapids the banks on both sides of Lake Timiskaming are extremely bold, and, as a rule, rocky, and frequently for several miles present unbroken cliffs. The hills on both the Ontario and Quebec sides of the lake rise very steeply from 350 to 600 feet, with but few minor and unimportant breaks where some of the larger streams flow in. Throughout the whole of the distance from Mattawa the tributary streams all show a very abrupt descent to this valley. Above the mouth of the Montreal the topographical outline changes somewhat suddenly, and the shore, though still in many places steep and abrupt, is not continuously so; while wide and open valleys covered with drift separate the still high hills. The west shore of the lake is especially steep and regular, and until Haileybury is reached no flat of any appreciable extent occurs. Near the northwest corner of the lake large and comparatively level tracts exist that extend far beyond the boundaries of the accompanying map, and are fast being opened up for settlement.

The eastern, or Quebec shore, presents many deep and important indentations, and although numerous high and exceedingly rugged hills occur, they are for the most part separated from one another by flats of clay. These have in many instances been cleared and are at present occupied by prosperous farmers, the soil being good and yielding abundant crops.

The depression occupied by Lake Timiskaming extends in a northwesterly direction, but becomes divided into two subsidiary valleys by the flat limestone promontory terminating in Dawson point. These valleys are occupied by the two important tributaries known as Wabi creek and the Blanche (or White) river.

It has always been known that the Ottawa river is, in many portions of its course, very deep, but no accurate information regarding its depth was published until Mr. Thos. Guerin, C.E., examined that part of the river above Mattawa.* Those soundings were, however, few in number and confined chiefly to Seven League lake, although a few were obtained in the vicinity of Chief island on Lake Timiskaming. Mr. Guerin states that Seven League lake was sounded in several places, the depth obtained being generally about sixty feet. In one place it was 397 feet, but in no place was it found to be less than thirty feet deep. The sounding-line on Lake Timiskaming was unfortunately only 120 feet long, and on continuing the soundings south of Chief island it soon failed to reach the bottom.

During the progress of the geological survey several calm moonlight nights were spent in sounding Lake Timiskaming. These soundings were commenced at the Opimika narrows where the deepest water was found to occur in close proximity to the western shore which is here steep and rocky. The bottom is composed of coarse gravel and boulders, and the lead showed a narrow and tortuous channel whose greatest depth was forty-five feet.

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*Annual Report, Minister of Public Works, 1884-85, pp. 106-107.

Four more soundings were taken in going north, in the next mile, showing a gradual deepening with a gravelly and ultimately a sandy bottom. These soundings were respectively 55, 47, 75 and 111 feet. About midway between Main Channel islet and the west shore the channel is sixty-five feet deep, while that between this island and the eastern shore is only fifty-five feet. It is evident that there exists at this point a considerable bar, due to the deposition of morainic or drift material, of which Main Channel islet (wholly composed of boulders) forms the culminating point.

From this place to within half a mile of McMartin point three soundings were taken, showing an increase first to 95 feet, then 139 feet and 183 feet, while three soundings taken at this point showed 211 feet in mid-channel, and 198 and 127 feet, the latter being within 200 yards of the western shore. Opposite McMartin point the lake again appears to shallow somewhat, and the deepest sounding near the centre was 157 feet, while half way between this and the western shore it shallows still further to 130 feet. Again it would seem that this shallow portion is caused by an accumulation of morainic *débris*, of which McMartin point forms the shoreward extension.

All of the above soundings showed a bottom composed of very fine gravel or sand. To the north of McMartin point the lake deepens rapidly and maintains a very uniform depth as far as the mouth of the Kipawa river. About a mile north of McMartin point the depth noted was 425 feet, while still farther north, opposite Latour's mills, in mid-stream, the depth found was 460 feet. This great depth was maintained close to either shore, for a sounding taken within ten chains of the western shore showed 455 feet, while one taken an equal distance from the eastern shore was 320 feet. About a mile farther north the lake is 423 feet deep and again in mid-channel opposite the Buffalo rock it is 430 feet deep. The deepest sounding made was taken a little over a mile south of the Kipawa river, about the middle of the lake, the depth being 470 feet. Going northward the lake shallows, and opposite the mouth of the Kipawa is only 362 feet deep. Throughout this interval of great depth, from McMartin point northward, the whole bottom was found to be covered by a soft, unctuous, grey clay or ooze into which the lead sank a foot or more.

The depth ascertained at the mouth of the Kipawa remains uniform to within a mile of the combined mouths of the Montreal and Matabitchouan rivers, where it is 347 feet. Northward the lake gradually shallows, and opposite the mouths of these streams has been partly filled up by an extensive deposit of sand and gravel that forms the bottom in this neighbourhood. These streams cannot, however, account for the vast accumulation of loose material which is here evidently present, for the lake is over a mile wide, and for more than a mile in length has been filled up by a deposit varying from 100 to 150 feet in depth. Farther, the lake shallows considerably to the north of these streams, while the reverse would have been the case if the whole of the material had been brought down by them. This extensive bar has probably been deposited in the first place as a lateral moraine in the shelter of the bay in the rocky hills that occur at the mouths of these rivers, while the material subsequently transported and laid down by the streams has reformed and modified these deposits, producing the somewhat wide delta now found.

Opposite the mouth of the Montreal river the depth of the lake in the middle is 275 feet, while about three-quarters of a mile farther north this again decreased to 256 feet. Still farther north the lake deepens rapidly, and two miles north of the Montreal river the soundings showed a somewhat uniform depth of 400 feet. A little over half a mile southeast of Roche McLean the lake is 378 feet deep, while opposite the north end of Quinn point it is 370 feet. Here again a bar composed of boulders and clay with a little sand extends from the northeast end of this point for nearly a quarter of a mile, with only about five feet of water at ordinary summer level. In the centre of the large open space to the north of Quinn point the lake is 348 feet deep, while in the middle of the Narrows, opposite Pointe à la Barbe, it is only 170 feet deep. In the open space opposite the mouth of the Little river it is 175 feet deep, thus showing a rather uniform depth in this position.

The Old Fort narrows is a very decided contraction occasioned by two bold hills of sand, gravel and boulders. The deposition of the material at this point was evidently determined by a pre-existing rocky narrows, the higher portions of which may be seen protruding from the surrounding mantle of sand and gravel. During the retirement of the ice-sheet up the valley of the lake a large amount of morainic material was deposited at this place, thus still further reducing the channel. In the channel, immediately opposite the Hudson's Bay Co.'s old store, the first sounding showed a depth of thirty-one feet, which was gradually increased to about seventy-five yards from the west shore; while less than thirty yards from the west shore the depth was found to be forty-six feet. To the north the lake gradually deepens, first to eighty-eight feet about an eighth of a mile north of the Narrows, and finally to 120 feet about half a mile north. In the opposite direction, or southwards, on the other hand, the lake deepened first to sixty-five and then to 130 feet within less than an eighth of a mile.

There seems, therefore, to be no warrant for the supposition that this barrier of sand, gravel and boulders extended at one time completely across the lake, for, if such had been the case, it appears probable that the removal of this material would have resulted in the accumulation of a considerable deposit immediately south of the Narrows, which is not found, as the descent on the south side is much steeper, in fact nearly as steep as the angle of repose, under the conditions, for gravel and sand.

Our soundings did not extend farther to the north, and although the western shore-line is still very steep and abrupt it is not probable that the great depth characteristic of those areas to the south of the Narrows is maintained in this direction, although occasional localities with considerable depth may doubtless be found, presumably in the neighbourhood of the western shore.

The highest water in this part of the Ottawa is in general occasioned by the melting of the snow in spring, and occurs usually about the latter part of May, while the time of low-water is during September or October, according to the setting in of the autumn rains. During the summer months the Ottawa is remarkably and quickly affected by very heavy or long continued rainfalls. In ordinary seasons this difference in level varies from twelve to fourteen feet, but in 1887, and again in 1894, Lake Timiskaming and this portion of the Ottawa showed the astonishing difference of twenty-one feet between the two extremes of high-and low-water. Both of these years were, moreover, remarkable for an extremely heavy snowfall during the preceding winter, thus furnishing conditions for an extraordinary spring freshet, while the succeeding summers were notable for excessive and long continued drought, and the lowest water occurred during the month of September.

One of the most marked effects occasioned by this difference in level is the corresponding difference in the fall of the Long Sault rapids that separate Lake Timiskaming from Seven League lake, and the accompanying increase in the fall of the rapid at the outlet of the latter, known as "The Mountain." During times of low water the fall in the Long Sault rapids is almost fifty-five feet, while at high-water it is only forty-nine feet. On the other hand, during times of freshet, the Mountain rapid has a fall of seven feet, while at low-water there is only a fall of a little over three feet. During the same time Seven League lake has a total fall of two and a-half feet in times of high-water, and at low-water there is only a fall of half a foot from the north to the south end. These seeming anomalies are thus explained by Mr. Thomas Guerin:*—"The Long Sault * * * is divided at its head by an island into two channels, the level of the bottom of the eastern channel being about seven feet below that of the bottom of the western channel which becomes dry at low-water. * * * The outlet from Seven League lake is at the Mountain rapid, and the capacity of the channel here is less than the united capacities of the two channels, which constitute the outlet from Lake Timiskaming. Hence the latter channels during high-water pour a greater quantity into Seven League lake than the outlet of the latter is able to discharge, thus causing Seven League lake to rise, while Lake Timiskaming falls so that the difference of level must be least at high-water. Again when the level of Lake Timiskaming falls so low as to render the western channel dry then the outlet from Lake Timiskaming will be confined to the eastern channel, which is nearly of the same dimensions as the outlet of Seven League lake, but as the area of the latter lake is many times less than that of Lake Timiskaming its level must fall faster, and the difference of level must be greater at low-water than at any other time.[*]"

The rate of discharge from Seven League lake was measured by Mr. Guerin at the current immediately above the Mountain rapid, on the 21st of August, 1884, and found to be 16,383 cubic feet per second. From a comparison of the levels then prevailing it was calculated that the rate of discharge during times of high-water would be 25,100 cubic feet per second, and during low water 14,800 cubic feet per second.

The trend of the Ottawa valley, from its confluence with the Mattawa to the foot of Lake Timiskaming, is nearly northwest, making a considerable angle with the direction of the foliation of the gneissic rocks along its banks. At the mouth of the Mattawa a sharp elbow is formed, the valley below that river turning nearly east, in close correspondence with the foliation of the gneisses, and coinciding in direction with the depression occupied by the Mattawa river. The sharpness of this elbow is further accentuated by the fact that, for several miles above this point, the course of the Ottawa river is nearly north-and-south.

The river from Mattawa to the foot of Lake Timiskaming is interrupted at intervals by heavy rapids, three of which occur on the first fourteen miles, while the Long Sault, seventeen miles farther up, is six miles in length.

The first rapid, four miles above the Mattawa, is now known as La Cave. It is about half a mile in length and is divided into two leaps, the lower of which was formerly known as La Cave, while the upper portion was called the Demicharge Chaudron, or Chaudière. The combined fall is nearly ten feet, divided into two nearly equal parts. The river between the Mattawa and La Cave rapids averages about a quarter of a mile in width, although in one or two places where bays are present this width is nearly doubled. Antoine creek is the main tributary in this interval, coming in from the west and draining in its course the larger portions of the townships of Mattawa and Olrig, its source being in some small lakes situated in the southwestern part of the township of French.

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[*] Annual Report, Minister of Public Works, 1884-85, pp. 107-108.

From La Cave to the next rapid, known as Les Erables, is a little over three and a half miles, while the width averages about a third of a mile, and occasionally somewhat less. Les Erables rapids are a little over half a mile in length, with a descent of nearly thirteen feet. Latour island, at the foot of this rapid, and almost in the middle of the current, shows a large number of pot-holes worn out in the rock. All stages in the process may be seen from the incipient canals, where the eddies have commenced to wear down along the jointing planes that cut the rock to holes ten feet in diameter. In a few instances several holes are seen to have been so greatly hollowed out that they ultimately joined at or below the surface.

Cotton creek enters from the east a short distance below the foot of Les Erables rapids, forming a beautiful cascade as the water tumbles over the rough ridges of gneiss which impedes its progress. This stream drains a number of lakes, of which Lake Memewin, situated about four miles to the east of the river, is the largest, being four miles long, and very irregular in outline. Scarcely three miles and a half intervenes between Les Erables and The Mountain, where the whole volume of the river flows through a narrow channel obstructed by rocky reefs and islets. About a mile above Les Erables rapids another stream enters from the east, with a steep descent into the valley of the Ottawa. This stream, now known as Snake creek, drains a number of small lakes, the largest of which is Snake lake, while the headwaters are in a small lake, from which only a short portage is necessary to reach Obashing lake. It thus formed a portion of the old winter route, which left the Ottawa river at the mouth of this creek and reached Lake Timiskaming a short distance below the Opimika narrows. About a mile below the Mountain rapid one of the highest hills was ascended and found by aneroid barometer to be 520 feet above the surface of the water. The average height of the hills on either side would, therefore, be little less than 500 feet.

Seven League lake is a stretch of navigable water nearly seventeen miles in length, extending from the head of the Mountain to the foot of the Long Sault rapids. The banks in most places are steep and rocky, and one or two places perhaps deserve special mention. Devils Garden bluff, on the east side, presents a sheer precipice of gneissic rocks, and receives its name from the fact that a patch of wild onion grows near its summit. Above this, on the west side and only a short distance below the foot of the Long Sault rapids, there is a sharply accented hill thickly overgrown with small pine trees, which, from its marked resemblance to the characteristic headgear of the Canadian "habitant," has always received the designation of "La Tuque." This is a rather important and well known land-mark.

Three important tributaries enter Seven League lake. The first of these, known as East creek, has its source near the eastern limit of the southern map-sheet, and is thus not more than seven miles long, reaching about six and a half miles below the foot of the Long Sault. The next stream, however, which enters on the west side about half a mile farther north, is much larger, and named Jocko river, after a half-breed of that name. Formerly the stream was known as the Siconaguisipi or Blackstone river, a name appearing in Sir William Logan's report on the region, although on his manuscript map it is designated as the Porcupine river. The main branch of this stream heads in a lake about two and a half miles long, bearing the same name, and situated about the centre of the township of Osborne, a little over twenty miles in a straight line from the outlet. Its northern branches drain the northern parts of Osborne and Garrow townships, and also a considerable area of unsurveyed land between these townships and Nevin's base-line. The southern branches drain almost the whole of the townships of Stewart and Lockhart, this area being but slightly less than seventy square miles. The river has carried down a quantity of loose material which fills up a large area of the lake in the vicinity of its mouth. It flows through a steep, narrow valley, and in debouching on the lake the channel makes a sharp bend northward through the gravel sand, thus forming what has often been called a "square fork." This delta is 200 yards wide and about a quarter of a mile long, and may owe its origin partly to glacial accumulation and deposition. If it occurs as a result of stream action it evidences a river of much greater volume than that which now occupies this valley.

The Obashing is the third stream of importance entering Seven League lake in a bay on the east side close to the foot of the Long Sault rapids. The lower portion of this stream meanders through a sandy flat which extends inland for some distance. The upper portion of the stream, however, is exceedingly rough and rapid, showing a total fall of about 300 feet in a distance of scarcely three miles. It affords an outlet to a large number of lakes in the region to the south of Kipawa lake, the largest of which is Obashing lake. The name is of Chippewa origin, and refers to the narrows which divide the lake into two very nearly equal portions. It covers an area of about eleven square miles, and measures ten miles from east to west, with an average width of from one to three miles. Two large tributaries enter the eastern end of the lake, the most northerly being known as the Otter river.

The Long Sault rapids separate Seven League lake from Lake Timiskaming, and are caused by a great accumulation of very coarse gravel and boulders, many of the boulders at the head of the rapids are exceedingly large, measuring from twelve to fifteen feet in diameter. The rapids are usually very narrow and crooked, and a little over six miles in length. Very little rock *in situ* can now be seen, although it is evident from the topography that the detritus was deposited in a pre-existing shallow narrows. On the east, or Quebec side, the drift material forms a comparatively level space, varying from a quarter to half a mile in width, along which the railway-line is constructed. With skilful canoemen it is customary to run the Long Sault rapids in the larger voyaging canoes, but five portages and tracking lines are necessary when an ascent is made. The three lower portages are on the east side of the stream, and the two upper ones on the opposite bank.

Two streams fall into the Ottawa at the Long Sault, one from either side. McDougall creek, which flows in from the west at the Crooked rapid, takes its rise in some small lakes about ten miles to the northwest, and Gordon creek enters about a mile below the head of the Long Sault. Logs are brought from Kipawa lake by an artificial channel into Gordon creek, down which they are run. The total fall of Gordon creek from Kipawa lake is about 300 feet, nearly 250 feet of which is below Pike lake in a little over a mile.

Lake Timiskaming is usually regarded as commencing at the head of the Long Sault. The name means literally "at the place of the deep dry water," doubtless referring to the existence of the extensive clay flats in the northeastern portions of the lake which are sometimes dry. The lake is sixty-one miles long in a bearing N. 26° W., with an area of about 125 square miles. From the head of the Long Sault to the Narrows the lake is about a quarter of a mile wide, but at the foot of the Narrows it increases in width to about a mile, on account of Thompson bay, situated on the east side. Both shores are steep and high, and in several places there are almost perpendicular cliffs over 200 feet in height. On the Ontario side especially the hills are covered with a good growth of pine almost to the water's edge, which effectually conceals the rock beneath. A portion of the Quebec side, between the Narrows and Schooner island, has, however, been almost denuded by fire of its original forest growth, and exposes the rough and broken ridges of gneiss. Schooner or Ship island evidently represents the apex of a bouldery shoal, as no evidence of a rock *in situ* could be found. Presquîle, about a mile above the head of the Long Sault, has been designated as an island, and although comparatively deep bays approach close to one another on the north and south sides a small neck of land unites the so-called island with the eastern shore. It evidently represents an older accumulation of morainic material which in so many places blocks the channel of the river.

The Opimika narrows are about two miles in length, and very crooked and contracted towards the northern end. High rocky hills form the immediate coast-line on the west side, but on the east side the shore is composed of sand, gravel and boulders, forming a flat over a quarter of a mile wide to the base of the rocky hills. The greatest contraction is towards the north end, where the shore-lines are only a little over a hundred yards apart. Two creeks enter the Ottawa at the Opimika narrows. The largest one, now known as White creek, drains two or three small lakes between this point and Kipawa lake, the largest of which, White lake, is over half a mile in width, and two miles in length; the eastern end approaching within about three miles of Kipawa lake. The other creek is known as Green creek, and enters from the west side, draining some small lakes in that direction.

Above the Opimika narrows the lake widens almost immediately, and from this point as far north as the mouth of the Montreal river it has an average width of from three-quarters of a mile to a mile. The shores are very bold, often exhibiting nearly vertical precipices of rock for many miles at a stretch. Occasionally small portions of the shore-line are composed of sand and gravel, but high trees rise almost immediately behind. McMartin and Ouellette points are small, low, projections running out a small distance into the lake and are composed wholly of sand and gravel except in the case of McMartin point, where some of the solid rock projects through this loose material. In the vicinity of McMartin point a considerable amount of stiff grey clay was noticed, and a bank of this contains a large number of very irregularly shaped calcareous nodules, but no fossil remains were found in them. The hills on either side of the lake are from 300 to 500 feet above the surface of the water, and the highest, known as the King of the Beavers, rises to a height of about 600 feet. These hills evidently form the edges of an undulating plateau which extends inland on both sides, and in which the valley of the lake has been excavated. Buffalo rock is another well known topographical feature, consisting of a rocky precipice on the west shore of the lake, and so named from a mass of vegetation upon it, which has a fancied resemblance in outline to a buffalo.

Six tributaries may be mentioned which flow into the Ottawa between the Opimika narrows and the mouth of the Matabitchouan river. The first of these is Opimika creek that enters a beautiful sandy bay on the west side, known as McLaren bay, about half a mile north of the Narrows. The water of Opimika creek is extremely clear and cold, abounding in speckled trout. Although its actual source is in a small lake about nine miles to the southwest of the Narrows it derives most of its water from two lakes some four miles to the southwest, which are supplied by a series of large springs. One of these lakes is called Emerald lake, and is remarkable for containing a deposit of shell marl which is described in that portion of the report treating of economic geology. The small pond at the head of the stream is 580 feet, by barometer, above Lake Timiskaming.

About three miles farther on Ottertail creek reaches the lake from the west. This stream forms a portion of a route to the west. The main or southern branch takes its rise in a small lake some twenty miles to the southwest in the township of Hammell, within a mile of Spruce lake, at the head of the Tomiko river. About a mile above McMartin point a small stream enters from the east, draining White Beaver lake, and three miles south of the mouth of the Kipawa river another small stream enters which is notable as being the old Indian portage-route to Lake Kipawa.

The next stream is the Kipawa river, forming the outlet to a great number of large lakes, many of which are outside the boundaries of the present map. The largest of these lakes is of course Lake Kipawa, which is nearly thirty-two miles in a straight line from north to south, and, with its intricate shore line of bays covers an area of 120 square miles. The Kipawa river is nearly nine miles in length, with a total fall of about 300 feet, and has a number of powerful rapids and chutes in its circuitous course. At the mouth is a very fine chute. The Matabitchouan and Montreal rivers, which enter the lake at the same place, are elsewhere separately described.

North of the Montreal river Timiskaming lake gradually widens. The western coast-line continues to be rather even and unbroken and is also as a rule steep and rocky. At the Crowsnest rock, opposite Bryson island, as well as at Manitou rock opposite Mann island, there are sheer precipices that extend for several miles, varying from 150 to 200 feet in height. The east side of the lake shows more irregularity in outline, and large areas of level land exist, from which, however, bold hills rise in places. There is much more cultivable land in the aggregate than the often rocky character of the lake-shore would indicate.

Below the Old Fort narrows there are only a few small and insignificant islands. Roche McLean, so named after an old North-west Company fur-trader, as well as the island north of Pointe à la Barbe, are both connected at low-water with the western mainland by narrow bars of sand and gravel. Moose rock is a huge boulder of breccia-conglomerate about thirty feet in diameter, situated some four miles south of the Narrows. North of the Narrows there are several islands, of which the most important are Bryson island, Mann island and Chief island, the latter being a well known topographical feature. It is high and rocky, and at low-water is connected at its eastern end with the mainland by a bar composed of boulders and clay; although, during the early part of the season, there is often sufficient water to permit of the passage of the steamer. To the northwest of the island a similar bar exists, which, at low-water, prevents the steamer proceeding any farther, although the channel inside is quite deep. The presence of this boulder barrier is probably due to its deposition, in part at least, in a crack or rift in the glacier that evidently occupied the valley of the Blanche river towards the close of the glacial period.

The northern part of the lake, from the Old Fort narrows to the mouth of the River des Quinze, has more the appearance of a lake than any portion farther south. The deepest water is to the west of Mann and Bryson islands, and is the route usually followed by the steamer. At ordinary summer level it is impossible for a steamer drawing six feet of water to pass between Bryson island and the Quebec mainland, and the lake for a long distance outward, opposite Wright's mine, is comparatively shallow. Kelly, or, as it is now called, Priests bay, where the chief settlement of the district is situated, presents a long stretch of gently sloping clay flats, extending out from the shore opposite the village of Baie des Pères, and, usually, towards the end of August and in the month of September there is not more than five feet of water at the end of the long wharf, so that for a considerable portion of the season the steamers are compelled to anchor fully half a mile from shore, and lighter their passengers and cargo.

The north shore of the lake is divided into two deep bays by the high rocky promontory terminating at Dawson point. The high limestone table-land of which this forms a part is over two miles in width, presenting a very steep escarpment of light cream-coloured limestone facing eastward and running in a N. N. W. direction beyond the borders of the map. Wabi bay is a little over two miles wide and three miles in depth, receiving at its head the waters of Wabi creek, at the mouth of which is situated the promising settlement of Liskeard. Wabi creek is a stream of considerable importance, rising beyond the north boundary of the map and draining a large area of arable land to the northwest, most of which has recently been laid out in townships and subdivided into lots. The borders of Wabi bay are in general low, with a marshy fringe along its northwest shore, while the water is extremely shallow and the shore difficult of approach except by means of the very crooked and narrow channel which the stream has hollowed out on the hard clay bottom. The northeastern part of the lake is divided into two bays known as Sutton and Paulson bays, separated from one another by the low marshy delta marking the mouth of the Blanche and Quinze rivers. The greater portion of Sutton bay is a low sandy flat almost completely dry at low-water.

When the lake is at its ordinary summer level there is scarcely a foot of water covering the extensive clay flats in the vicinity of Chief island except in the various channels which the steamers entering in this vicinity have hollowed out. During low-water, occuring in September of 1887 and 1894, the greater part of these clay flats was exposed, the water being confined to these comparatively narrow channels. Three large tributaries enter the lake in this neighbourhood and a fourth, known as Apika creek, about eight miles in length, drains the western portion of the township of Guigues. The largest of these streams is the one which really constitutes the upward extension of the Ottawa river, now known as the Rivière des Quinze or Quinze river. The other two, in the order of their importance, are the Blanche river and the Otter river, often also called Ottertail river, especially on the maps issued by the Crown Lands Department of Quebec. Only about five miles of the lower portion of the Blanche river is shown on the Lake Timiskaming map-sheet. The source of the stream is in Round lake, situated about forty-four miles from its mouth in a northwesterly direction, but owing to curves in the river the distance is nearly sixty miles. The waters of the Blanche river enter the lake through four somewhat intricate channels, between three low marshy islands formed by the large amount of loose material deposited annually by this stream. Two of these islands, known as Wright and Rousselet islands, are of considerable size. The deepest channel is called the Chenal du Diable, and is navigable for small steamers at high-water. The next channel farther south is known as the Crow channel and is fairly deep, but the other two channels, which are more in line with the upward course of the stream, are almost completely choked with sand and other detritus, so that they can scarcely be navigated by canoes during ordinary stages of the water.

About five miles from its mouth the depth of the river varies from sixteen to twenty-four feet, and the width from 320 to 400 feet, and at a distance of twenty miles from its mouth it is 220 feet wide and eight feet deep. Here a small rapid occurs, with a fall of about two feet, but above this is a quiet stretch of water for nearly six miles farther. It will thus be seen that, at low-water, the river is navigable for a distance of twenty-five miles for steamers drawing under three feet, while at its highest stage this distance is increased to over thirty miles. The Blanche river has cut its channel through a thick deposit of drift material, composed chiefly of clay, and the sections thus furnished are probably the best in the whole district. The valley consists of a series of four or five rather extensive flats or terraces, rising, one above the other, to the northwest of the lake, and evidently forming the continuation northward of the depression occupied by Lake Timiskaming. Near its mouth the banks of the river are quite low and subject to inundation, with large areas of tamarack and spruce swamp. As the stream is ascended, however, the banks gradually increase in height, and thirty miles inland they are more than one hundred feet above the level of the stream. Twenty-five miles from the lake the banks are eighty or ninety feet high, and furnish a good section, which is as follows in descending order:—First, two or three inches of vegetable mould, then about a foot of reddish-brown sand merging into a grey clay, and below this, again, a bluish clay, which extends to the base of the cliff, forming the bed of the stream. Bluish clay is exposed, according to McOuat,* in the bed of the river all the way to Round lake, but about half-way up is overlain by a rather coarse, brown sand, which, in its turn, farther up, is again overlaid by clay. Six or eight miles below Round lake, where the cliffs are upwards of a hundred feet high, the middle portion consists of sand, while at the base and summit nothing is seen but clay.

The Otter river drains by far the larger portion of the area to the southeast of this part of Lake Timiskaming. The main stream rises about six miles southeast of Lac aux Feves, where it occupies the same depression as Chemagan and Hay bays of Lake Kipawa. Its channel is very tortuous, and in its lower portion has an average width of about 100 feet, with a depth of ten feet, while its rate of discharge was measured by Mr. Guerin as 229 cubic feet per second, or less than one half that of the Blanche, and its velocity twenty-six feet per second. It is navigable by canoes without interruption for a distance of about ten miles from the mouth, and is frequently used by the settlers in going to and returning from North Timiskaming.

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*Report of Progress, Geol. Surv. Can., 1872-73, p. 134.

About six miles from the mouth the Cameron branch enters, and, with a general course of nearly east-and-west, has its headwaters in a small lake only a mile west of Lac des Quinze. This tributary also serves to empty two considerable lakes, known as Long and Sassaganaga, the former about three miles in length, but with an average breadth of scarcely a quarter of a mile, while the latter is two and a half miles long, with a somewhat uneven shore-line and containing several islands, and has an approximate breadth of a little over half a mile. The south branch, or Duford river, drains the larger portion of the township of Duhamel, rising in a small marshy lake about the centre of the township. This stream is rather crooked, even in its larger bends, while it meanders in a very tortuous manner through clay flats.

Geological Description.

The village of Mattawa is built upon a bouldery terrace of morainic origin, which, subsequent to its deposition, has been modified to a considerable extent by the scouring action of water. This boulder-covered field or plateau has a somewhat uneven contour, but in general it may be said to rise from thirty to seventy feet above the river. It is only one of many similar occurrences to be found in the neighbourhood of the Ottawa river, all of which seem to owe their accumulation primarily to deposition from a melting detritus-laden glacier. This bouldery terrace begins nearly a mile up the Mattawa river and extends a little over half a mile down the southern bank of the Ottawa. In the angles formed by the junction of the two streams it has its maximum development, producing a bar consisting almost wholly of boulders and coarse gravel, which stretches nearly across the river, leaving a deep though narrow channel near the Quebec shore. The boulders about Mattawa vary in size from a few inches to as many feet in diameter, while many of them measure from ten to fifteen feet across. By far the larger number of these erratics consist of very evenly folioted gneiss, and have not been carried far from their original positions. Some are red and grey granite, while a few are of greenish gabbro or diabase. Recent cuttings show that the bouldery layer overlies silts and other fine deposits. A well defined old river-channel occurs, running through the rear portion of the village between the main street and the railway station, which has evidently been followed by the Mattawa or its antecedent stream. It leaves the Mattawa about a mile above the mouth, and reaches the Ottawa at the foot of the rapid, nearly three-quarters of a mile below.

On the north side of the river a steeply scarped though somewhat narrow terrace rises to a height of nearly eighty feet above the level of the river. Near the junction with the Ottawa this terrace is composed of well-rounded fragments or small boulders with coarse gravel and sand, this material being in a much finer state of division than that on the south side.

Opposite the village of Mattawa, on the north side of the Ottawa, is "Mattawa mountain," about 600 feet high. It is composed of a greyish granite-gneiss, consisting of the usual alternation of lighter and darker bands, causing a distinctly marked foliation. The strike of this foliation corresponds closely with the trend of the hill, being nearly east-and-west, while the dip is about 20° to the south. In places it contains an abundance of rather small garnets, especially numerous in the darker or more basic portions of the rock.

At many points this gneiss is cut by dikes of pegmatite, varying irregularly in breadth from a few inches to several feet. These pegmatites are composed usually of a flesh-coloured orthoclase or microcline and quartz. Occasionally a white plagioclase, probably oligoclase, was noticed in the same dike with the orthoclase, while the ferro-magnesian constituent is sparingly represented, if at all, and is usually biotite. The quartz is as a rule segregated in the centre of each dike, leaving an almost pure feldspathic margin of varying thickness. Many of these dikes cut the foliation at considerable angles, running from S. 40° W. to S. 55° W., while others, especially the smaller ones, conform very closely to the foliation.

It is quite apparent, from the many conflicting local dips and strikes observed in the area to the south of the Ottawa river, and extending for a few miles east of Mattawa, that the gneissic rocks rise into a series of small domes, each presenting quaquaversal dips; while, on the other hand, the complete examination of this small area has also shown that the grander structural features of these rocks exhibit a rather constant dip at low angles, varying in direction from south to S. 10° W. These gneissic rocks are well foliated and of a dark-grey colour where the bisilicate material is present in relatively greater quantity, while a prevailing reddish tinge is usual where feldspar present increases. Some bands exhibit the "augen" structure in great perfection.

About a mile east of Mattawa the main line of the Canadian Pacific railway has cut through the axis of one of the most perfect of these dome-shaped bulges. The gneiss occurs in alternating light and dark coloured bands which exhibit very sharp lines of demarcation one from the other. The main axis of this dome runs in a direction S. 80° E., the dips on the north side of the railway track thus turning from N. 80° W. all around to S. 80° E.; while on the south side of the track dips exactly the opposite of these may be noticed.

The gneisses contain a large percentage of pyrite, and all the joints and fissures are plentifully coated with brown hydrous oxide of iron due to the decomposition of this mineral. The rocks crumble and fall to pieces when exposed to the action of the atmosphere for any length of time, giving rise to a coarse brownish sand that constitutes much of the soil of the region surrounding Mattawa.

About a mile and a quarter east of Mattawa the gneiss has a dark reddish-grey colour, the reddish tinge being due to the presence of feldspar, which is in reality much more abundant in certain bands than in others. On the surface the gneiss presents a smooth hard crust that is evidently merely the result of weathering, while beneath this thin coating the rock has undergone somewhat advanced decomposition, being yellowish in colour and comparatively soft and friable. This outer induration is very frequently characteristic of the exposed surfaces of both gneisses and the Huronian sandstone and greywackés, and, as has been shown by Irving and Van Hise, is caused by the secondary enlargement of the quartz and feldspar individuals, the interstitial material constituting interlocking areas which are optically continuous with the original grains.

To the west of Mattawa the railway follows up the valley of a creek that empties into two small lakes, the larger of which is known as Earls lake. The shores of both these lakes are low and grassy, with only one rock exposure at the western end of Earls lake. Between Mattawa and Calvin stations the rock is usually well foliated granite-gneiss, although in one or two places it is very massive, and the foliation is either absent or quite indistinct. Some of the bands differ in colour from dark-grey to almost black where the biotite is exceptionally abundant; others are light-grey, while still others are of shades of flesh-red or pink where the feldspar is plentiful and is of that colour. The component bands are frequently so irregular in their development and in places so contorted, while the region as a whole has undergone such uneven truncation, that it is often exceedingly difficult to pronounce with any degree of certainty as to the direction of either the dip or the strike. In general, though, these rocks gradually bend round from S. 45° W. a little west of Mattawa, to S. 80° W. in the vicinity of Calvin, with a common dip at a high angle to the south. One of the pegmatite dikes noticed about two miles west of Mattawa is composed of a very large quantity of flesh-red feldspar in coarse cleavable masses, some quartz and a considerable amount of dark-coloured mica in large crystals and plates, doubtless a partially bleached biotite. All of the rocks are well rounded and glaciated, and although the striae are not very plainly marked some indistinct ones have a southwest direction, and are thus referrable to the period of general glaciation.

In the angle formed by the junction of the Mattawa and Ottawa rivers, and to the north and east of these streams, the foliation of the gneiss shows a curious fan-like arrangement, the convergent lines pointing towards the Ottawa, where the gneiss shows a rapid change in strike from nearly east and west at the southern end of the rock exposure to N. 25° W. at the northern end. This structure is, however, only a local feature, and is confined to a small area. To the west this fan-like formation broadens, the bands near the southern end curving round rather sharply to the southwest to meet those exposed on the shores of Boom lake and in the vicinity of the Plein Chant rapids on the Mattawa, where the gneiss strikes from S. 30° W. to S. 60° W. with a southeasterly dip $<$ 40° to 45°. To the north, as the Ottawa river is ascended, on the west shore the strike of the gneiss changes first to the west and then to N. 75° W., which latter seems to be the general direction of the foliation in the vicinity of the Cave rapids. At the bluff on the east shore the rock is composed of alternating bands of light and dark-grey micaceous gneiss, evidently of the ordinary granitite variety, and shows a strike of N. 55° E. and a dip to the south $<$ 10° to 15°. About this again the foliation exhibits a change in direction, and about three-quarters of a mile below the Cave rapids a strike of S. 75° E. was noted, with a dip southward $<$ 20°. A little above the rapids the evenly foliated grey gneiss trends in a northeasterly direction, dipping to the southeast $<$ 30°. Between the Cave and Les Erables rapids the granitite-gneiss, which in the more basic bands seems to contain some hornblende in addition to the biotite, varies in strike from S. 70° W. to N. 70° W., with a southerly inclination.

Les Erables rapids are caused by the outcrop of ledges and islets of gneiss, which obstruct an already much contracted channel. The strike is N. 70° W., while the dip is northwards at an angle usually considerably less than 10°. A little above these rapids the foliation has an almost east-and-west direction, while near the mouth of Snake creek the strike is N. 80° E., and the dip S. $<$ 70°. From the head of Les Erables rapids to about half a mile beyond the mouth of Snake creek the exposures, which were very closely examined, show a gneiss composed of alternating bands of light and dark-grey colour. The bisilicate present, which from its preponderance gives the dark colour to certain bands, is biotite, and the rock is thus a granitite-gneiss composed essentially of feldspar (chiefly orthoclase), quartz and biotite. Besides these constituents there are others which in places are so abundant as to characterize the rock. The principal and most interesting of these is cyanite, although individuals of an almandine-garnet are usually numerous, especially in the more basic portions; while graphite was noticed finely, though rather thickly, distributed through the rock. Cyanite of a prevailing blue colour is frequently so plentiful as to characterize large exposures of this gneiss. It occurs in rectangular or flattened prisms, which are very long and blade-like in their habit, presenting round, jagged, or irregular terminations.

About a mile below The Mountain rapid the high hills on the east shore are formed of alternating bands of light and dark-grey garnetiferous granitite-gneiss, striking S. 55° W., and dipping southeasterly < 45° to 60°.

At the foot of the Mountain rapid the gneiss is more massive in structure, although still preserving a distinct foliation that runs nearly east and west, while the dip is to the south < 35° to 40°. In places it is filled with small crystalline or irregular fragments of garnet, while the rock in general has a distinct reddish colour. The Mountain rapid runs for the most part in a strike of the rock, which is a dark-grey, well foliated gneiss. The ridges and islets are composed of this gneiss, presenting a strike varying from S. 50° E. to S. 55° E., with a dip to the northeast < 20° to 30°.

About a mile above the Mountain rapid, on the west side, the dark-grey, micaceous or granitite-gneiss strikes S. 70° W., with a dip to the south. About one and a half miles above this point a grey gneiss was noted with a decided foliation, exhibiting a series of beautiful curvings and twistings, while the general strike is N. 60° E., with a dip to the southeast < 65° to 70°. About four miles above the Mountain rapid a massive, fine-grained, red gneiss was noticed, associated with some more evenly foliated, grey gneiss; the whole dipping south < 40° to 80°. In the vicinity of the narrows of Seven League lake, and for some distance beyond, the gneiss is in many places much contorted, and usually of a dark-grey colour, owing to the prevalence of the ore basic bands. In many places the rock runs in long curves, presenting a gentle undulating dip, which often approaches horizontality, while at other points not far removed the bands are almost on edge. Beyond the narrows on Seven League lake the gneiss, which has a grey colour and is well foliated, strikes about S. 65° E., with a southerly dip at a low angle, generally from 20° to 30°. Opposite La Tuque, on the east shore and below the mouth of Obashing creek, the lighter coloured bands, which are reddish, alternate with those of a dark-grey. These constitute a granitite-gneiss, which generally dips S. 25° W., < 10° to 20°, although in some places it seems perfectly horizontal, and in others it is much contorted.

At the foot of the Long Sault the reddish granitite-gneiss dips S. 20° W., $< 25°$. In many places along the shores of the northern part of Seven League lake the darker and more basic bands of gneiss contain epidote in very considerable quantities, indeed sometimes so abundant is this mineral as to give a yellowish tint to the band in which it is contained.

The country between the Long Sault rapids and Lake Kipawa is composed of high, rocky ridges of flesh-red and dark-grey gneiss, the former prevailing, while the alternation of both produces a marked foliation in the whole mass. The darker bands are made up mostly of the coloured constituents, while the lighter ones show a relatively greater quantity of quartz and feldspar. The general strike varies from S. 50° E. to S 60° E., while the dip is under 30°. A thin section of what was regarded as a typical specimen of this gneiss showed it to be a quartz-mica-diorite-gneiss, although it is probable that other and more acidic portions would show the ordinary granitite-gneiss, as well as the hornblende-granitite-gneiss, to be present. The rock, as examined under the microscope, showed the chief mineral constituents to be plagioclase, quartz, some unstriated feldspar (probably orthoclase) and a little microline, hornblende, biotite and epidote, with smaller quantities of titanite, pyrite, zircon, allanite, apatite and hematite.

On the Big Obashing lake the gneiss is usually well foliated. often of a light-grey colour, although some portions present reddish-coloured bands where the feldspar contains much iron oxide, and the general strike in the vicinity of the narrows varies from S. 66° E. to S. 75° E. with a dip to the south $< 15°$ to 30°. At the east end of the little island, in the bay out of which the road goes south to the small lake at the headwaters of Snake creek, the gneiss is composed of alternating reddish and dark-grey bands, in places somewhat contorted, and shows a general strike of S. 85° E. with a dip to the south $< 70°$ to 80°. Near the east end of Obashing lake the dark-grey well foliated gneiss strikes S. 84° E., and is either quite vertical or dips at a very high angle to the south.

Near the outlet of Little Obashing lake the gneiss, which is distinctly foliated and has a reddish colour, strikes east and west, dipping south at an angle of about 35°. The smaller lakes to the southwest of Little Obashing lake generally present high shores which are well wooded and green to the water's edge, so that there are only limited opportunities afforded for ascertaining the trend of the bordering gneiss. On a small island in Thompson (or McConnell lake), however, grey gneiss was noticed dipping S. 20° W. at a low angle.

Near the head of the Long Sault, on the west shore of the Ottawa, the gneiss is composed of alternating light and dark bands. Many of the lighter bands have a flesh-red colour where the feldspar is abundant, while others are greyish or nearly white. The dip is S. 30° W. < 20°.

There are comparatively few exposures of rock between the head of the Long Sault and the Opimika narrows, and the strike at some of these is hard to ascertain with any degree of certainty. The general strike seems, however, to be S. 55° E., which is apparently maintained as far as Schooner or Ship island. On the east shore, opposite this island, the gneiss, which is exceedingly well foliated in alternating bands of light-grey, flesh-red and dark-grey colours, dips S. 10° W., < 30°.

To the south of the Opimika narrows, on the west side, and nearly opposite Lumsden depot (Opimicong P. O.) is a grey, rather fine-grained, evenly foliated micaceous rock, showing lenticular areas of quartz and feldspar which are comparatively free from coloured constituents. The microscope shows the rock to be a hornblende-granitite-gneiss composed chiefly of quartz, orthoclase, plagioclase, microcline, biotite and hornblende, with smaller quantities of ilmenite associated with leucoxene, sphene, apatite, calcite, zircon and epidote. The dip of this gneiss is S.W. < 45°.

This exposure marks the southern end of a great curve in the gneissic rocks, the Opimika narrows conforming closely with the strike of the rocks in their bend. At the southern end the strike is northwest; about half-way through it has changed to S. 75° W.; at the north end of the Narrows the strike is N. 15° W., while still farther north on the same side it bends around to N. 30° W., and near the mouth of Ottertail creek the rock strikes N. 35° E.

The gneiss, in this interval, is of the usual grey micaceous variety occurring in alternating light and dark bands, while the dip is to the west or northwest at high angles, usually about 65°. A thin section, cut from a specimen obtained at the exposure immediately below the mouth of Opimika creek, showed the rock to be a granitite-gneiss, composed chiefly of quartz, orthoclase, plagioclase and microcline, with biotite, epidote and sphene as its principal coloured constituents.

In the region to the southwest of the Opimika narrows the country is well wooded, and the few rocky outcrops encountered have a general southwesterly strike. Near the small bridge on the old McLaren lumber road, crossing Opimika creek less than a mile from the lake-shore, the gneissic rocks are very evenly and distinctly foliated, showing interlaminations of reddish light-grey and dark-grey material, the whole having a strike of nearly north and south and dipping west < 20°. Two miles southwest of the lake other small outcrops of a light-grey granitite-gneiss occur, dipping S. 50° W. < 35°. Near the end of McLaren road the rock is concealed for the most part by sand, but here and there hummocks of gneiss occur. One of these, situated about three-quarters of a mile from the end of the road, is composed of grey well foliated gneiss dipping S. 80° W. < 20°.

To the northwest of the Opimika narrows are situated Long and White lakes, which empty into Lake Timiskaming a short distance northwest of Lumsden depot. These lakes are noteworthy as affording an opportunity of tracing in some detail the general outline of an immense curve in the strike, that, starting at the south end of the Opimika narrows with a direction N. 40° W., circles around to S. 65° E. at the Beauvais narrows on Lake Kipawa. On Long lake the gneiss is composed of successive bands of reddish-grey, grey and flesh-red colours, which vary in strike from N. 20° W. to N. 7° W., while the attitude of the layers changes from nearly horizontal in the southwestern part of the lake to an inclination to the west of 35° in the northeastern part. On White lake the rocks curve around gradually to N. 53° E., and on the north shore the gneiss has a strike of only a few degrees south of west. These rocks are light-red, reddish-grey, light-grey to dark-grey gneisses, the layers running in low, broad undulations with a prevailing southerly dip at angles varying from 5° to 10°.

On the north side of White lake there is a reddish contorted gneiss very plainly foliated, a ferromagnesian constituent being present in long slender dark-greenish bands, while in the wider and more feldspathic portions such coloured constituents are almost entirely absent.

To the northeast of McMartin point, on the portage going to White Beaver lake, the gneiss is exceedingly well foliated, running in long generally straight and somewhat continuous bands of alternating light and dark-grey colour, and varying in strike from N. 40° S. to N. 50° E., with a prevailing northwesterly dip at high angles generally about 75°. Exposures on the south shore of White Beaver lake exhibit a light reddish-grey gneiss in successive bands of lighter and darker colours, the whole showing a changeable strike from N. 60° E. to N. 68° E., while the folia are nearly if not quite vertical.

Between McMartin point and Latour's mills the east shore of Lake Timiskaming is very high and precipitous and for considerable stretches presents perpendicular rocky cliffs. For two miles above McMartin point the gneiss is comparatively massive and chiefly of the red variety, although grey bands may be noticed marking the foliation. The rock has, in general, a dip N. 65° W. < 35° to 80°. The combined action of the weather and the waves of the lake have served in many places to remove an appreciable portion of the softer and more micaceous bands, leaving the red feldspathic parts standing out in rather prominent relief, smoothed and planed as a result of glacial action. The surface now exposed exhibits, in great perfection, even the smallest bendings and foldings which these rocks have undergone. In the last half mile of the distance already mentioned the gneissic rocks seem to strike approximately with the trend of the shore-line, exhibiting beautiful examples of contortion, while in other places the rock lies in a series of low undulating folds. Above this, for a little over four miles, and extending a short distance beyond Latour's mills, are almost continuous exposures of micaceous or granitite-gneiss, which is so evenly laminated that slabs could readily be obtained of almost any dimensions for flagstones. The strike is very regular, generally about N. 15° E., and the dip easterly < 50° to 80°. The alternating bands composing the gneiss are usually reddish, greyish and dark-grey in colour.

On the western shore, for a short distance both above and below McMartin point, the rocks are somewhat similar in character, the strike varying from S. 35° W. to S. 90° W., while the inclination, which is towards the northwest, changes from an angle of 65° to 35°.

About a mile above McMartin point, on the west shore, the gneiss is much contorted, and in one place presents a low, dome-shaped anticlinal arch, the banding of the gneiss dipping either to the northwest or southwest at low angles. Nearly two miles above McMartin point, or ten miles south of the mouth of the Kipawa, the gneiss is made up of alternate layers in which a relatively greater amount of feldspar and quartz or biotite and hornblende are respectively present. The darker bands have yielded somewhat extensively and unevenly to atmospheric decay, the feldspathic layers standing out in rib-like forms. The strike is chiefly to the southeast, while the bands have either an almost vertical attitude or dip at high angle, never less than 70°, in a southeasterly direction. Microscopical examination of a specimen representing the more basic portion of the rock shows it to be a quartz-mica-diorite-gneiss, composed essentially of plagioclase, orthoclase, quartz, hornblende, biotite and epidote, with sphene, apatite and zircon as accessory constituents.

Opposite Latour's mills, and for a short distance both north and south, the gneiss is well laminated, exhibiting precisely similar features to that on the opposite side of the lake. The feldspathic bands, which are usually flesh-red, are rather fine-grained and contain little quartz or mica, while the darker bands show a superabundance of biotite and other coloured constituents.

In several places, associated with this gneiss and evidently caught up in it, are irregular masses of a dark-green, almost uralitic diabase, with somewhat large and glistening scales of dark-brown mica. The surface of this rock weathers very unevenly, presenting a very rough and pitted character. This roughness is increased by a series of intricate, reticulating dikes of a fine-grained aplite or granite that stand out in strong relief. Under the microscope the rock is seen to be an altered diabase, the hornblende showing undoubted evidence of having been derived from pyroxene, while traces of a rude ophitic structure can still be detected. The other minerals present are biotite, plagioclase, garnet and iron ore.*

Between Latour's mills and the western end of the old Indian portage-route to Lake Kipawa the gneiss is not so regular as that farther south, and in some places runs parallel with the shore-line, while at others it forms considerable angles with this direction, making at least one great bend, which is shown on the accompanying map.

The rocks are either vertical or dip at high angles to the east and southeast. A little south of the Indian portage there are some dark-green, almost black, glistening bands of amphibolite, which occur for the most part interfoliated with the prevailing gneiss. These present many of the characteristics of parallel or interfoliated dikes, and some portions of them cut across the foliation, but their true relations were not studied in detail, so that it cannot be stated with certainty whether they are of later origin than the gneiss with which they are associated. The microscopic examination of two thin sections shows, that although it must be referred to as quartz-mica-diorite-gneiss, it differs in many particulars from the basic bands of the ordinary gneiss to which this name has also been applied. It has very evidently been derived from the shearing of a basic eruptive rock, resulting in its more or less complete re-crystallization, and several places were noticed throughout the region where a similar rock could be traced directly and continuously into the ordinary massive phase, which for some reason had escaped such complete deformation. One of the localities where this can perhaps be seen to the best advantage is on the shores of one of the smaller bays running to the northwest, and forming part of Leonard inlet, on the west coast of Shabosagi or Wicksteed lake. This amphibolite, or quartz-mica-diorite-gneiss, is composed of quartz, plagioclase, hornblende, with an iron ore (probably titaniferous) and epidote, garnet, apatite and zircon. Associated also with the gneiss near this

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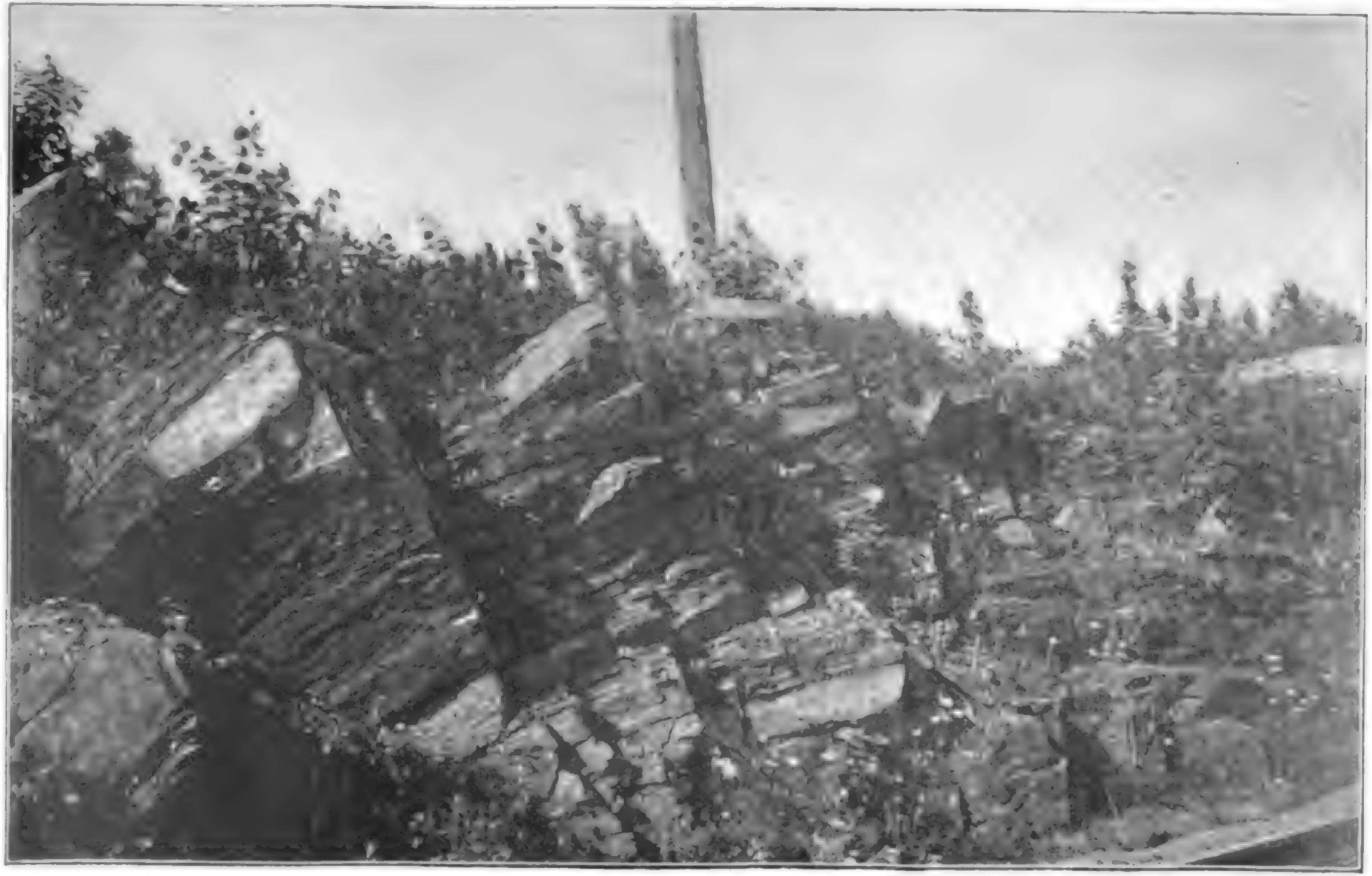
*Section No. 53.



CUTTING IN GNEISSIC ROCKS, ONE MILE EAST OF MATTAWA, ON MAIN LINE OF C.P.R.

Showing the dome-like structure frequently noticed in highly differentiated gneisses.

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point is some of the uralitic diabase already described as occurring on the west shore of the lake.

From the Indian portage northward to within about two miles of the mouth of the Montreal river the rocks present the usual alternation of reddish, grey, and almost black bands. The strike of the foliation is somewhat irregular or divergent, but the general directions are indicated on the accompanying map.

Martel point, as well as the shores of the small bay to the south, and some small rocky islets lying close to the eastern shore of the lake in this vicinity, are composed of a dark-green, almost black diorite.

From Buffalo rock northwards along the west shore the strike of the gneiss does not show any wide variation, the general direction being from S. 45° W. to S 65° W. with a dip to the southeast < 40° to 80°. The general colours are shades of light and dark grey, with some reddish bands where the feldspar has been stained by iron. A specimen obtained from an exposure nearly opposite the mouth of the Kipawa shows a fine-grained, grey, evenly foliated, micaceous rock, slightly discoloured throughout by iron oxide. The microscope shows the rock to be a granitite-gneiss, consisting chiefly of orthoclase, quartz, biotite and epidote and bearing a close resemblance to the gneiss exposed near the north end of the Opimika narrows, although somewhat finer in texture.

The contact between these gneissic rocks, mapped as Laurentian, and the Huronian rocks, is exposed on the west shore of the lake about two and a quarter miles south of the mouth of the Montreal river. Immediately south of the small creek which enters the lake from the west four and a half miles south of the Montreal river the gneiss has a strike of S. 60° W. with a dip S. 30° E. < 85°, while in the bed of the creek itself the rock is apparently of a coarse dark micaceous variety, decomposed almost wholly to a chlorite-schist associated with some steatite or soapstone. For nearly a mile north of this the shore is composed of a flesh-red gneissic granite, striking from N. 60° W. to N. 70° W. and dipping to the southwest at high angles. The point about a mile to the south of the contact is occupied by a massive dark mica-diorite or uralitic diabase, intersected in various directions by dikes of red gneissic material. Near the junction the Laurentian is represented by a light-reddish or reddish-grey gneissic granite, with somewhat indistinct foliation but no lamination. The rock is massive, rather coarse-grained, containing a comparatively small proportion of bisilicate material. Under the microscope it is seen to be a granitite-gneiss, the feldspar having undergone somewhat advanced saussuritization, while the biotite originally present has been wholly converted into chlorite.

The rock in contact with this gneissic granite on the west shore, representing the Huronian, is the typical and widespread breccia-conglomerate described by Sir William Logan as "slate conglomerate" or "chloritic slate conglomerate."

This rock contains numerous angular as well as rounded fragments, among which those of a somewhat coarse flesh-red granite are the most abundantly represented. These granite pebbles are composed chiefly of flesh-red orthoclase, with a smaller quantity of greyish translucent quartz and relatively little biotite, which has evidently undergone very advanced alteration to chlorite. Occasional specimens of a dark-green rock, which seems to be an extremely fine-grained and altered diabase, were noticed, while irregular and angular fragments of simple minerals, chiefly quartz and feldspar, are rather abundant. This coarse fragmental material is held in a dark-green slaty matrix, in which chlorite and epidote are the most abundant constituents. Both the larger fragments and matrix have been subjected to intense and long continued pressure. The coarser fragments are squeezed out in a direction at right angles to the line of junction, while the softer and more yielding matrix curves around these inclusions.

The granite and conglomerate are very closely and firmly cemented together along their line of junction, and it would be quite easy, were it not for the broken and jointed character of both rocks, to secure pieces exhibiting portions of each in the same hand specimen. The line of contact in the immediate vicinity of the lake runs in a general direction of S. 75° W., but this line is not perfectly straight, as the granite has a somewhat sinuous edge which is followed very faithfully by similar irregularities in the schistose structure of the breccia-conglomerate. It is quite evident from an inspection of the coarser fragments that they have not been derived from the disintegration of the gneissic rocks with which these clastics come in contact, for the minerals composing them are much coarser in their method of crystallization and of a deeper red colour, resembling closely in these particulars the granite exposed on both shores of the lake to the north of the Old Fort narrows. Besides, the rock in immediate contact with these Laurentian gneisses often contains far fewer fragments of such materials than exposures of similar rock farther removed from the line of junction.

The Huronian to the south of Montreal river, on the west shore of the lake, is, as a rule, represented by a fine-grained feldspathic sandstone, generally of a pale greenish-grey colour. Microscopic examination of a specimen obtained about a mile and three-quarters south of the mouth of the river shows this rock to be made up of angular, sub-angular and occasionally of rounded fragments of orthoclase, quartz, plagioclase and microcline, cemented together by similar material in a finer state of division, with some chlorite, epidote and sericite often filling in the smaller interstices. In many places this rock is very hard and flint-like in character, breaking readily under the hammer with a splintery or conchoidal fracture. It occurs in somewhat thin beds, often shaly, dipping S. 83° W. < 20° while a set of cleavage planes which have been developed as a result of pressure dip S. 20° E. < 70°. At the point just north of the contact the rock is a greenish-grey compact slaty greywacké, which has evidently been subjected to great pressure and alteration, for a distinct foliation or schistose structure has been developed, the various bands of the rock being squeezed out into lens or pod-shaped areas, while pronounced curves in the direction of the schistosity may be observed, due to the equal resistance deformation offered different bands and portions of the rock. At the immediate line of contact the parallel structure of both Laurentian and Huronian comform with one another, these being produced as a result of mutual reaction, the resistance offered by the neighbouring clastic primarily determining the direction of the foliation in the granite, while the forces of upheaval in the gneiss have served to compress very materially the neighbouring clastic rocks. The Huronian strata which are here present form a curiously lengthened wedge-shaped strip between the Laurentian granite and the laccolithic or overflow mass of diabase which constitutes the summit of the "King of the Beaver."

On the east shore of the lake, from Martel point northward, the Laurentian is represented almost altogether by a pale flesh-red granite, showing little or no bisilicate material, the principal coloured constitutent being epidote, which is somewhat abundant. The contact between this rock and the breccia-conglomerate of the Huronian is, on the east side of the lake, about three miles north of the Montreal river. The actual contact is concealed, but outcrops of both rocks occur within a space of less than one hundred yards, and from these it would seem that the line intersects the shore at a point immediately south of a small creek which empties into the lake in this vicinity. Inland, the line is effectually hidden by overlying drift material, but its general direction seems to be very approximately N. 55° E.

The granite near the contact contains a large irregular mass of a coarse dark-green diorite. An area of finer crystalline chlorite-schist runs at right angles to the line of junction, and may represent either a small basic dike which has been subjected to pressure or an extremely altered fragment of the Huronian greywacké which has been caught up in the granite.

In the breccia-conglomerate the matrix is often present in very subordinate quantity. The most abundant fragments are of the usual biotite-granite type, while others of a pale greyish granite rock are seen in thin sections under the microscope to consist of phenocrysts of plagioclase or orthoclase embedded in a fine-grained quartz-feldspar groundmass. Besides these there are some fragments composed of a fine-grained altered diabase, and others of a greenish-grey slaty rock (resembling in a most marked manner the compact variety of the greywacké of the Huronian) and some grey quartz.

The material filling the interspaces is seen under the microscope to consist of a confused aggregate of scales and grains of chlorite and epidote, with abundantly disseminated particles of iron ore and fine granules of sphene and epidote. At first sight this conglomerate, occurring as it does in very massive beds with no pronounced parallelism in the arrangement of the larger fragments, seems devoid of any definite structural features, but a closer inspection shows the strike to be about N. 50° E. while the dip is to the southeast < 10°. As here exposed it forms a hill about four hundred feet in height, presenting a very sharp and abrupt northern face, while to the south it slopes more gradually down towards the line of demarcation between the two formations. To the north and west this rock is succeeded by a dark greenish-grey, compact, slaty rock which seems to underlie the breccia-conglomerate, although in other sections the conglomerate occurs at the very base of the Huronian. The exposures at this place, however, are not in immediate contact, so that the relations of the two could not be ascertained with certainty.

On the small island in Lavallee bay the rock is a fine-grained, greenish-grey greywacké, much squeezed and jointed, breaking with a conchoidal and somewhat splintery fracture. The small island near the east shore about a mile southeast of Roche McLean is also formed of a similar greenish-grey compact feldspathic sandstone rather massive in structure.

The western shore of Lake Timiskaming, from the Montreal river to Roche McLean, is occupied by the massive, bedded, breccia-conglomerate which dips in a westerly direction at an angle of 15°. This rock has already been described. A specimen obtained from an exposure about two miles north of the Montreal river, however, showed the matrix to be relatively more abundant than usual. The diabasic pebbles are also more plentiful than those of red granite, while fragments of simple minerals predominate greatly over those of composite rocks. The quartz and feldspar fragments are sharply angular, while the composite individuals are as a rule somewhat rounded.

In the conglomerate near Roche McLean the pebbles are more rounded and much more sparsely disseminated through the matrix. Pieces of an extremely altered diabase were noticed, and also some of a fine-grained greatly crushed quartz, filled with small scales of sericite and chlorite. The reddish pebbles are of the prevailing type of biotite-granite or granitite. Roche McLean itself is a large rounded and glaciated hummock of this breccia-conglomerate, separated from the west shore by a narrow interval at high water.

To the north of Roche McLean the western shore for a distance of a little over a quarter of a mile is occupied by a series of dark-grey slaty rocks, the only structural feature discernible being the planes of cleavage, which dip northward at a high angle. This comes in contact with, and is somewhat altered by, a small intrusion of diabase which is doubtless an extension of the large mass which comes out on the eastern shore at Quinn point. To the north of this diabase the massive breccia-conglomerate again outcrops, and is penetrated by a mass or dike of similar diabase, but with this slight interruption continues northward along the shore almost as far as Island point.

This point is so named because of the existence at high-water of a narrow and shallow channel separating it from the western shore. It is composed of a much squeezed, contorted and altered slaty greywacké, containing a considerable quantity of epidote. It is pierced throughout by small and intricate granitic intrusions which have evidently assisted materially in hardening and otherwise changing. To the north this rock is again succeeded by a conglomerate, containing the usual abundance of granitic fragments embedded in a dark-green diabasic or dioritic paste, resembling a diabase-tuff. About a quarter of a mile north of Island point this rock comes in contact with a fine-grained hornblende-granite that forms the shores of the bay to the south of Pointe à la Barbe, extending inland in a northwesterly direction and possibly connected with the mass of granite exposed on the western shore of the lake above the old Fort narrows, although it is very different in appearance from this.

In many places this granite shows dark patches, generally oval or rounded in outline, varying in diameter from a few inches to a foot or more. These patches are caused by the segregation of the coloured constituents and the more or less complete exclusion of the feldspar and quartz. They constitute what are familiarly known as the 'dark spots' (ausscheidungen) so commonly seen in granites, and evidently represent the first-formed nuclei in a slow-cooling magma.

Quinn point is the name usually applied to a series of rugged hills that form the shoreward extension of a pronounced range that extends with little interruption for some miles to the northeast. The rock composing these hills is a dark greenish-grey uralitic diabase, in which the ophitic structure is generally apparent to the eye. The rock varies in texture, the coarse phases assuming more of the holocrystalline or granitoid structure characteristic of gabbro. Jointed structure is very perfectly developed, one set of planes dipping westward < 80° while another series dips eastward < 12°. The rock is composed chiefly of plagioclase, which frequently contains much disseminated iron oxide, giving it a red hue, and hornblende, which has evidently resulted from the alteration of augite. A small quantity of some carbonate (probably dolomite) a little interstitial quartz and titanic iron ore were also noticed.

The Gull Rock islands are situated about half a mile north of Quinn point. There are two of them, presenting low rounded and well glaciated surfaces but little raised above the high-water level of the lake and almost destitute of vegetation. The rock composing them is the breccia-conglomerate containing very numerous and often well rounded pebbles and boulders, chiefly of red and reddish-grey granite, with some of a compact dark-green altered diabase and a few of a fine-grained greatly crushed quartzite. The matrix consists of the same sort of material in a finer state, with greenish chlorite filling in the smaller interspaces.

Moose rock is the name applied to a huge boulder of rounded outline perched upon a shoal. It is almost thirty feet in diameter and must have been detached from the cliffs of similar rock on the east shore, over a mile to the northward of its present site, and has been moved during the glacial period.

The northern end of Point à la Barbe, on the west shore, about two miles south of the Old Fort narrows, is formed by an island which, at high-water, is divided into two almost equal parts, connected by a slender rocky peninsula. The rock composing it resembles the finer-grained, hardened and altered matrix of the breccia-conglomerate. On the opposite shore a steep rocky point juts out into the lake forming a narrows. The breccia-conglomerate is here exposed for a considerable distance along the shore either way, reaching to within about a quarter of a mile of the mouth of the Little river. The shore-line at this point rises steeply into a hill nearly four hundred feet in height, forming the shoreward extension of a conspicuous ridge that runs for several miles to the northeast, and marks the southern limit of the Little River valley. The rock has a strike of about N. 60° E., and a dip at low angle, less than 5°, to the northwest. The breccia-conglomerate here passes upward, by a gradual diminution of the larger fragments, into a compact, fine-grained arkose sandstone or greywacké that is exposed along the shore toward the mouth of the Little river. Under the microscope this rock is seen to be made up of partly rounded fragments of quartz, orthoclase, microcline and oligoclase, embedded in a matrix proportionately less in quantity and composed chiefly of chlorite and sericite. The fragments are nearly equal in size and show no pronounced rounding. The greenish colour is owing mainly to the large amount of chlorite present in the matrix.

To the north, and in ascending order, this rock is succeeded by a somewhat coarse-grained sandstone or grit, which forms the point immediately north of the mouth of the Little river. It also extends across the lake, occupying a corresponding promontory on the west side, known as Blueberry point. On both sides of the lake the rock occurs in thick massive beds, the stratification being shown only by the occurrence of conglomerate bands disposed in a somewhat constant direction. The rock is much jointed and broken, the fragments having a rough rhombohedral outline. To the north it is concealed in great part by the deep and extensive sand and gravel deposits that form the narrows opposite the Old Fort, but occasional outcrops may nevertheless be noticed. The rock extends along the east shore of the lake nearly three-quarters of a mile northeast of the Narrows, where it reposes directly on a massive red biotite-granite, although the actual junction is concealed. To the south of the narrows the rock occurs either in horizontal beds or dipping at a low angle to the northwest, but north of the narrows it seems to dip S. 35° E. $< 20°$.

A specimen obtained from a point composed of this rock about half a mile east of the Old Fort is a pale yellowish-green coarse-grained quartzite or grit. The thin section under the microscope shows it to be composed of quartz and feldspar embedded in a groundmass made up of pale yellowish-green sericite, for the most part present in exceedingly minute scales.

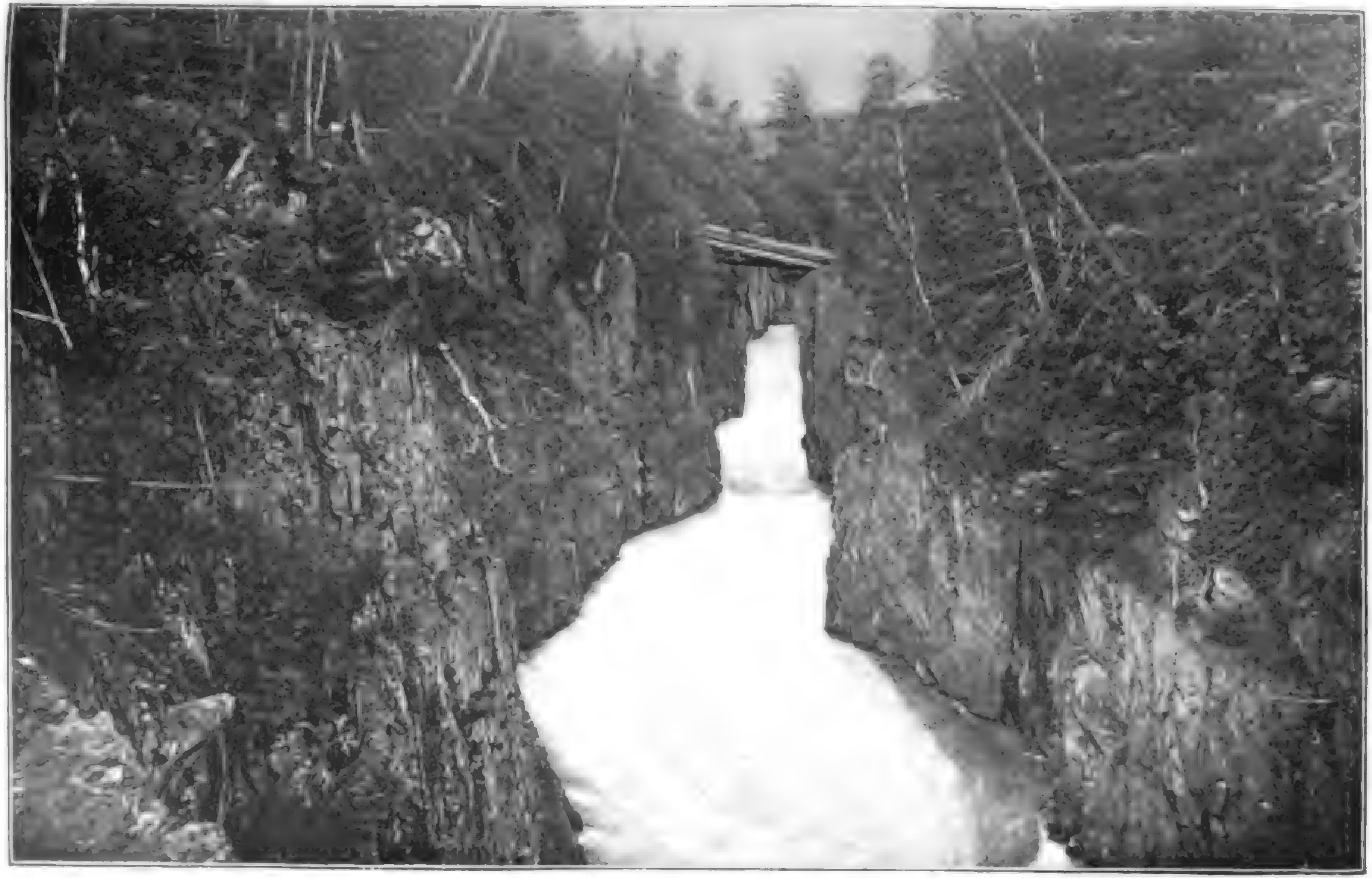
The granite which replaces the quartzite to the northeast of the narrows is exposed on both sides of the lake. It forms the western shore as far as Paradis bay, a distance of about four miles, and extends from half a mile to a mile inland. On the east side it composes Wine point and the southern shore of Kelly (Priests) bay, extending for a short distance west of the steamboat wharf to the point already mentioned, about three-quarters of a mile northeast of the Old Fort narrows. In all, these granite exposures cover roughly an area of six miles. Microscopically the granite is rather coarse in texture and of a deep flesh-red colour, owing to the marked predominance of the feldspathic constituents, all of which have been abundantly stained by iron.

Several small areas were noticed which have assumed a greenish colour owing to the epidotization and sericitization of a portion of the feldpsar; but such decomposed portions are proportionally insignificant, and the whole mass of the rock is extremely uniform, not only in colour but in the relative abundance and mode of development of its mineral constituents. The quartz occurs for the most part in somewhat rounded though irregular isolated areas, giving to the rock a conglomeratic or porphyritic appearance, a fact noted by Sir William Logan on the manuscript map embracing his survey of this lake made in 1845. Indeed the rock at first glance presents a marked resemblance to some of the brick-red quartz-porphyrites of Lake Superior. The ferromagnesian constituent is present in very small quantity and is now almost wholly converted to chlorite, the deep green colour of this mineral being probably the reason that the rock has hitherto been described as a hornblende-granite.

On previous geological maps covering this area this granite received the coloration usually applied to an acid eruptive, and as nothing was stated to the contrary it was very naturally inferred that, as such, it was of later age than the Huronian clastics with which it is associated. Sir William Logan in his early report does not give any details of its relations with the neighbouring stratified rocks, but only speaks of it as 'interrupting' the sandstones on Lake Timiskaming. During the progress of the present survey a detailed examination was made of the line of junction between this granite and the quartzite-grit. The best locality for investigating the various contact phenomena is situated in the small bay immediately west of the steam-boat wharf at Baie des Pères. In addition to the observations made on the ground a large suite of specimens was obtained illustrative of the line of junction for microscopic examination.

The facts obtained indicate the derivation of this quartzite-grit or arkose from the disintegration, *in situ,* of the granite, and are believed to form an almost unique example of the recognition of a portion of the original granitic floor upon which the Huronian sediments were deposited and from which they were derived.

In the vicinity of the line of junction between the two rocks the arkose or quartzite may be seen dipping away from the mass of the granite at a very low angle. The massive and jointed character of the beds of the arkose render it impossible to ascertain exactly all the minute details of the structural relations, but it is clear that the quartzite originally transgressed upon the surface of the granite almost horizontally. The granite has been unequally eroded and truncated, so that the present line of contact between the two rocks is undulating and irregular.



THE NOTCH OR GORGE, NEAR MOUTH OF MONTREAL RIVER.

Huronian greywacke-slates, much jointed and broken.

From a distance the line appears to be sharp and abrupt, the greenish colour of the quartzite showing up very clearly and distinctly in contrast to the red colour of the granite. A closer inspection, however, showed that there is a gradual passage upward and outward from the main granite mass to the overlying arkose. Macroscopically this passage consists in a gradual loss of the red coloration of the unaltered granite and the progressive appearance in its arkose of a yellowish-green hue, although along the immediate contact there is no visible change in the position of the constituent minerals.

Thin sections of the least altered portions of the granite exhibit a normal holocrystalline hypidiomorphic structure, with a tendency to idiomorphic development on the part of the plagioclase. The rock is a rather typical biotite-granite.

The quartz is somewhat cracked and the feldspar and biotite are more or less altered, but the rock, as a whole, is fairly fresh, and neither dynamic nor chemical forces have acted on it to such an extent as to render its true character and origin doubtful.

The junctions between the grains of the various minerals are sharp with no interstitial granulated material. The quartz is the ordinary granitic variety and is filled with minute inclusions, frequently arranged in irregular interlacing bands. Many of these, when highly magnified, prove to be cavities filled with fluids and often containing movable bubbles. The larger quartz grains under polarized light are seen to be made up of an aggregate of smaller grains with differing orientation, and the quartz has a distinct but not excessive undulatory extinction. The predominent feldspar is generally microcline, which can be seen in all its various stages of development from grains exhibiting only an indistinct moiré structure (Plate V., fig. 2), to those in which the cross hatching is perfectly developed (Plate V., fig. 2). The former, however, are the more abundant. It is turbid and much stained with iron oxide.

Plagioclase is as a rule quite abundant, and as already remarked exhibits a tendency to idiomorphic development. It is frequently embedded or intergrown with the orthoclase and microcline. The individual sections are broad and tabular, parallel to M., and show in great perfection the fine striation due to multiple twinning. Their outlines are more or less rounded. Carlsbad twins appear to be rare, but were occasionally observed. Zonal structure was noticed in only a very few instances and then was not at all pronounced. Like the orthoclase and microcline this feldspar is turbid in consequence of incipient alteration, and little scales of sericite are scattered through it. Inclusions of biotite are not infrequent. Bending of the twin lamellæ is rare, and exists only in a very slight degree. The mean of several determinations gave about +10° as the extinction-angle measured on M., between adjacent lamellæ, showing the feldspar to belong probably to the acidic end of the oligoclase series. As usual, where alteration is commencing, it shows itself in the centre of the crystals.

Biotite was the only ferro-magnesian constituent noted in the section. It forms irregular plates and flakes which are considerably altered to chlorite. The original brown colour of the material has been changed to a light-green, but without entirely obliterating the optical characters of the biotite. Inclusions of ilmenite with leucoxene are common. The mineral is not very abundant in this particular section.

Ilmenite is the iron ore present in the rock, always accompanied by its alteration-product leucoxene, and in some instances immediately associated with zircon and apatite crystals. Occasionally it may be observed replacing titanite, skeleton forms of the latter mineral, with sharply defined acute rhombic outlines, being filled with a mixture of carbonates, ilmenite, &c.

Chlorite is present in the rock as the final stage of alteration of the biotite.

A few irregular grains and crystals of zircon with well-defined zonal structure were noted, and exhibited the usual optical characters of the species.

Apatite is also present, but is not very abundant, occurring in small crystals and irregular grains.

Sericite, or an allied hydrous mica, is present in minute scales and flakes scattered through the feldspar, as the result of their alteration. Red oxides of iron are abundant.

At the other extreme the derived arkose or quartzite-grit show distinctly rounded and water-worn fragments, chiefly of greyish translucent quartz, varying in size from those only microscopically observable, to others which are sometimes an inch in diameter and are arranged in layers, which have evidently resulted from a sorting of the material by water action. These fragments are embedded in a groundmass or cement varying greatly in proportionate quantity and composed of a confused mass of minute sericite scales, being the argillaceous product of the decomposing feldspar.

The series of thin sections studied represent the various stages in the process of the degradation of the granite, in consequence of which the overlying arkose has been produced. The first step shows the development of microcline at the expense of the orthoclase, accompanied by an incipient sericitization of the feldspars, which is noticeable, to a considerable extent, even in the least altered specimens.

This is accompanied by marked alteration of the biotite to chlorite, the development of a distinct undulous extinction in the quartz and a cracking of some of the individual grains. A further stage is reached when the quartz is accompanied by the occurrence of mosaic-like areas between the larger grains, while these latter show very pronounced strain-shadows. The plagioclase likewise shows more frequent evidence of pressure in its twinning, the lamallæ often in these cases ending abruptly against cracks traversing the crystal. Bending of the lamellæ is more frequent, while the alteration of biotite to chlorite is more complete, and is frequently accompanied by the deposition of iron ore between the flakes.

This is closely followed, marking what may be called the third step in the transition, by an appreciable advance in the alteration of the feldspar, especially of the plagioclase, which becomes traversed by a series of cracks filled with sericite, the alteration extending outward into the main mass of the individual grains; but there is still no evidence of motion or shoving apart of the fragments.

A fourth and somewhat sudden advance appears when the alteration of the feldspars has proceeded to an extreme degree, while certain fragments have been shoved apart. Each individual grain still occupies the same relative position with regard to the other mineral constituents, but in places portions of quartz and feldspar, especially the former, can be noticed to have changed their position along certain cracks traversing the grains, the portions, however, being never widely separated. The plagioclase has been almost completely saussuritized, leaving the unaltered quartz grains in almost the original position occupied by them. The microcline and orthoclase, though badly decomposed, have not undergone such complete alteration as the plagioclase. The fifth stage is reached when both orthoclase and microcline have undergone somewhat complete decomposition, some of the individuals being now represented by an intricate mass of their alteration-products. This is accompanied by markedly uneven extinction in the quartz-grains, as well as by a cracking and separation of quartz and feldspar-crystals, which is more evident in the former.

The sixth and final stage in the process shows that the feldspars have almost entirely disappeared, although occasionally irregular cores of the unaltered mineral remain. The groundmass is now seen to consist of a fine-grained sericitic material, in which are embedded sharply angular or sub-angular fragments with very pronounced undulous extinction. The whole appearance of the rock, both in the hand specimen and under the microscope, is that af a typical clastic (arkose). There is every evidence, however, that much of the material has not undergone any very wide separation, while the quartz fragments still preserve a tolerably sharp outline, showing no pronounced water-action.

The suite of specimens obtained exhibits a still further stage, representing the whole process leading to a final assortment and rearrangement of the degraded material by water into bands of differing coarseness, and resulting ultimately in the formation of somewhat typical grits and conglomerates. The change has evidently been first mainly a chemical one, primarily attacking the biotite, then the plagioclase, microcline and orthoclase and leaving the quartz alone comparatively unchanged. The rock thus softened and loosened by decomposition has offered a less effectual resistance to the process of disintegration, the process ending finally in the complete breaking down of the surface of the granite mass and the formation of the overlying arkose.

The latter rock forms the western shore of the lake between Paradis and Martineau bays, opposite Bryson island, where it constitutes perpendicular cliffs that rise from 150 to 200 feet, while the hills immediately behind continue with a more gradual upward slope representing a considerable additional elevation. The rock occurs in almost horizontal beds striking with the lake, the structure seemingly representing a very shallow and narrow syncline; the beds near the southern part of the exposure in the vicinity of Paradis bay dipping west, while those near Martineau bay dip east or toward the lake. Almost the entire eastern shore of the lake, as well as Chief, Drunken and Bryson islands, is composed of this greenish quartzite or arkose, excepting only some small patches and strips of Silurian limestone, elsewhere described.

This greenish quartzite is remarkably homeogeneous, generally presenting the characters of a coarse quartzose sandstone or grit, but occasionally, as on Drunken island, becoming finer-grained. It is very hard, resisting well the general influences of weather, and occurs in thick and much jointed beds, generally of a pale yellowish-green colour, weathering in some cases to a light-brown to a depth of about an eighth of an inch. It sometimes has a brownish-green colour, in which case the exposed surfaces gradually assume a yellowish-green colour, and in occasional exposures it has a light-greyish tint with irregularly disposed spots or areas of a greenish colour.

In the vicinity of the narrows between the eastern shore and Bryson island, the rock dips N. 22° W. < 3°, and for the most part runs in low broad undulations. At a point on the east shore about one mile and a quarter south of Wright's mine this rock is seen directly superimposed upon the hummocky surface of a very massive breccia-conglomerate. The latter holds the usual pebbles of eruptive material, chiefly granite and diabase, and the chloritic matrix is very subordinate in quantity. The exposure presents a well rounded and glaciated outline sloping at an angle of nearly 60° to the north. At the summit, about forty feet above the water, the greenish quartzite seems to rest directly upon the conglomerate, presenting none of the usual transitional slaty or greywacké beds. The beds of quartzite seem to run in a somewhat undulating though approximately horizontal manner, apparently conforming with the line of outcrop of the conglomerate.

About three-quarters of a mile north of Wright's mine, on the same shore, there is a very interesting section showing the usual breccia-conglomerate at the base, very massive, and giving little or no structural detail. In ascending, however, it passes into a breccia, somewhat similar in colour and composition, but in which the lines of stratification can be readily distinguished. This is in turn succeeded by a fine-grained, brownish, well banded greywacké-slate, some portions of which cleave readily parallel to the bedding. This contains some smaller intercalated bands of the breccia, in which diabase and quartz fragments prevail. This is in turn overlain by another bed of conglomerate that passes upward into the yellowish-green quartzite-grit. The dip of these strata is to the northwest, at an angle of 10°, and the whole thickness of the section exposed is about fifty feet. The point immediately south and west of Wright's mine is likewise composed of the breccia-conglomerate, filled with pebbles of eruptive material, and the lode itself is situated in a similar though finer rock. In many instances the chloritic matrix is seen to wrap or flow around the enclosed fragments.

From Martineau bay northward, for about two and a half miles, the western shore is composed of a dark-greenish or greenish-grey, medium textured diabase. For nearly the whole of this distance this rock rises into cliffs, sometimes 200 feet high. The mass of the rock is much jointed and broken, and some of the jointage planes traverse it for considerable distances, thus simulating the basaltic structure so frequently assumed by similar basic eruptive masses. Under the microscope this rock is seen to possess a typical diabasic or ophitic structure, the interlacing idiomorphic laths of plagioclase penetrating the allotrimorphic individuals of augite. The plagioclase has been rendered more or less turbid by the development of the usual saussuritic products of decomposition, but many individuals still retain their clear and limpid character. The augite has, however, been altered to hornblende, the alteration being first to the fibrous form (the more abundantly represented), and then into the compact green

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trichroic variety, which is occasionally present. In some cases decomposition has proceeded so far that chlorite has resulted. A small quantity of unstriated feldspar in broad, irregular areas, that may be orthoclase, was noticed, while a considerable quantity of quartz fills in the interspaces. Occasional flakes and scales of brown biotite are likewise present, at times altered to chlorite. The ilmenite is almost entirely altered to leucoxene, although undecomposed portions remain. This diabase constitutes the vertical cliffs known as the Manitou or Devils rock, forming the shoreward extension of a huge mass that occupies the intervening area between Lake Timiskaming and the Montreal river, and which, extending across this river, forms a considerable strip on its southwest side. It also composes the area to the northwest, extending to the shores of Portage bay, on Bay lake, and beyond.

To the north of this diabase, on Lake Timiskaming, the characteristic breccia-conglomerate again comes in. The finer portions of the matrix are composed of a much hardened chlorite-slate or greywacké, while coarse-grained varieties resemble in appearance a diabase-tuff. The pebbles are usually abundant, and some of these resemble the diabase with which this rock is associated. Other pebbles are of quartz, and some are of a dark-grey compact felsite or greywacké, while a few consist of a pale-yellowish, fine-grained hälleflinta-like rock. Near a clearing on the west shore, a little south of Percy island, the rock exhibits a similar fine-grained chloritic groundmass, containing very numerous small fragments, chiefly of feldspar, while the rock itself as a whole greatly resembles a chloritized tuff or trap ash.

This is succeeded to the north (and doubtless in ascending order) by a fine greenish compact slaty greywacké, exposed in the vicinity of Farr creek, that continues beyond Lawlor's farm. For about two miles in the vicinity of Haileybury the western shore is occupied by Silurian strata. About two miles north of Haileybury the basal bed of the Silurian, consisting of a coarse grit or conglomerate, rests unconformably on the mammillated surface of the compact green slate of the Huronian.

This slaty rock, near the junction between the two formations, is very much hardened and presents alternating bands of greenish and brownish colours, so frequently characteristic of the middle member of the Huronian of the district, and these bands have a general direction of S. 70° W. The shore-line where the rock outcrops is more irregular than that to the north or south, with two small off-lying islets. About a mile north of the contact the slate passes into the breccia-conglomerate, containing many pebbles and boulders of greyish slate, compact quartzose and hälleflinta-like rocks, and pebbles of diabase of varying degrees of texture. The matrix in which these fragments are embedded is, as usual, dark-green in colour, while the whole mass of the rock presents little or no evidence of stratification. In general, however, it may be stated, with some degree of confidence, that the structure exhibited on the shore from the contact to the south as far as the diabase mass is that of a shallow syncline, the breccia-conglomerate forming the basal beds with the slates superimposed without break.

Where the fragments are abundant in the conglomerate there is frequently present a considerable amount of pyrite, which in some cases acts as a sort of cement, enclosing these fragments. The oxidation of this pyrite and its subsequent removal has left a series of rusty cavities that are rather characteristic of these outcrops.

The last exposure that may be mentioned here is one of the breccia-conglomerate which occurs on the northeast shore of Sutton bay, forming hills that are rather conspicuous and rise from a somewhat extensive marshy flat. The rock presents the usual dark-green chlorite groundmass. This matrix encloses larger pebbles of red and grey granite, green diabase of several varieties and degrees of coarseness, and some fine-grained compact greywacké-slate, with a few of grey quartz. The larger fragments, especially those of granite, possess more or less rounded outline, while most of the smaller fragments, and especially those representing basic eruptive material, are decidedly sharp and angular. The rock is massive and for the most part structureless, but planes that possibly represent the original bedding dip N. W. < 25°.

RIVER AND LAC DES QUINZE.

The River des Quinze doubtless received its name from the fact that fifteen portages have to be made between Lake Timiskaming and Lac des Quinze, but this number may be diminished under some circumstances. Although the stream presents considerable stretches of deep water with little or no current, it is, as a whole, wild and turbulent. The river has a general east and west direction, and in a straight line is about thirteen miles long, although this distance is increased to eighteen miles by means of flexures. It enters the northeastern corner of Lake Timiskaming in a shallow indentation known as Paulson bay. With the Blanche, which reaches the lake a little over a mile farther west, it forms a delta with low marshy islands, and only two channels can be utilized for purposes of navigation. The more easterly of these two channels is seldom used on account of its being extremely shallow, while the western or main channel is of good depth. About half a mile from the lake a rather narrow and crooked, though deep and navigable, channel joins the Quinze with the main portion of the Blanche. This is known as the Chenal du Diable, and during freshets the waters of the Blanche follow this channel to the lake, but during the summer months the current in this channel is reversed, and a considerable portion of the waters of the Quinze reach the lake by this somewhat circuitous route.

The River des Quinze is generally a little over a mile wide. The banks, especially on the northwest side, are low and liable to inundation. The southeast bank is somewhat higher at Miller point, with a hill of gravel and boulders.

In ascending the river the first rock-exposure is on some small islets nearly opposite the North Timiskaming P. O. (McBride's). The rock is the breccia-conglomerate of the Huronian, the matrix being a very compact, fine-grained material of dark green colour, through which are disseminated occasional pebbles as well as angular fragments of the greyish granitic rock. There is little or no evidence of stratification. The further ascent of the river exhibits a corresponding rise in the geological scale. The first three rapids come very close together and are not more than a mile in all. The first and second rapids each show a descent of about twelve feet. The third has a fall of about sixty feet and is one of the worst on the river. The rock exposed at the several portages is a dark-grey micaceous slate, the cleavage or foliation planes, which are the only distinct structure exhibited, showing abundant small black scales of biotite.

There are many lighter coloured streaks running through the rock, more or less parallel with one another, which seem to be composed mainly of feldspar and quartz. These occur in irregular curving and often branching and lenticular areas giving a decided foliation to the rock. They do not appear to represent coarser and more quartzose bands of the darker coloured slates with which they are associated, but are more or less veinlike in structure and secondary in their origin. The strike and dip could not be ascertained with any degree of certainty, but the rock, from its lithological character and apparent stratigraphical position, represents the lower portion of the slate, or middle member of the Huronian, overlying the breccia-conglomerate noticed as occurring near the mouth of the river.

Above this third portage there is an interval of three miles of deep unobstructed navigation to the fourth rapid, immediately above the mouth of Tiger creek, an important tributary coming in from the north side. The river is here divided into several channels by rocky

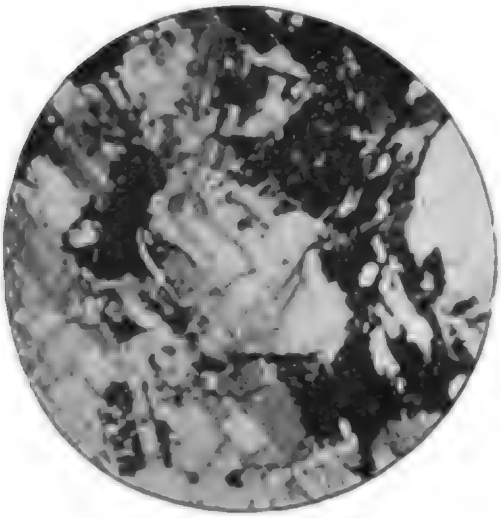

FIG. 1.

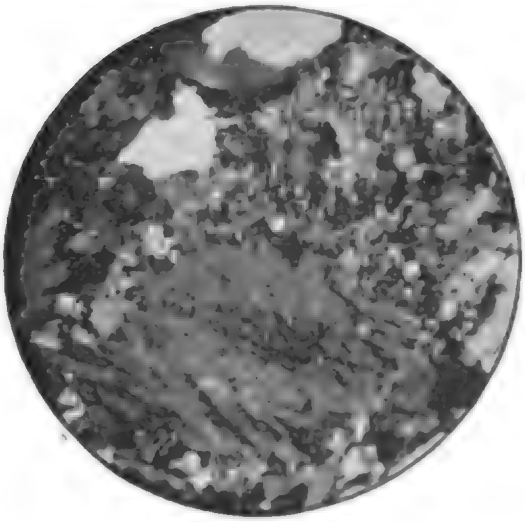

FIG. 2.

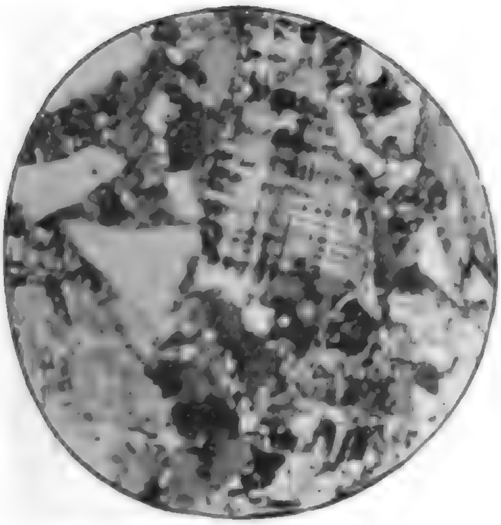

FIG. 3.

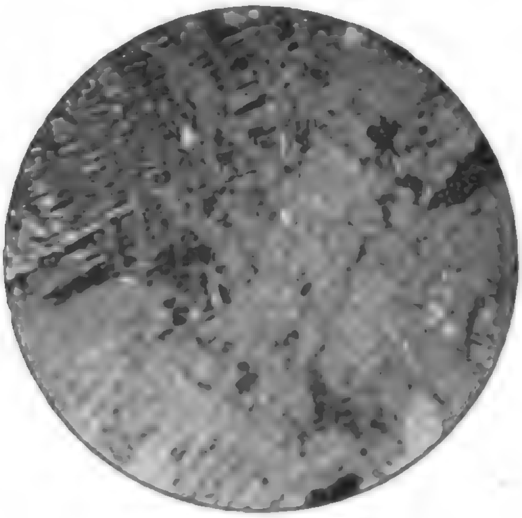

FIG. 4.

FIG. 1.—Biotite-granite or granitite, near Cedar point, east side Lake Timiskaming—orthoclase, quartz, plagioclase and chloritized biotite. × 52.

FIG. 2.—Effects of pressure, granulation, and the formation of microcline in arkose, near Baie des Pères, Lake Timiskaming. × 52.

FIG. 3.—Formation of microcline and moving apart of minerals, of arkose resulting from degradation of granitite, near Baie des Pères, Lake Timiskaming. × 52.

FIG. 4.—Decomposition of feldspar (microcline) *in situ*, forming arkose, near Baie des Pères, Lake Timiskaming. × 52.

islands, the largest of which, Mann island, is nearly one and a half miles in length. The main channel which runs to the north of this is one long succession of heavy rapids with a total fall of about eighty feet. The portage-route, about two miles long, follows the north bank.

On this portage the rocks met with are dark greenish-grey slate, much cleaved and jointed and probably dipping to the southeast. In places they show considerable alteration and development of sericite, the alteration being greatest near the eastern end of the portage. These slates continue to the upper end of the island where they are interrupted by a mass of uralitic diabase and amphibolite, about three and a half miles in breadth, which extends southward and is probably continuous with similar rocks exposed in the northeast corner of the township of Duhamel and the eastern portion of the township of Guigues. This rock is often massive, but not without traces of foliation, and towards the eastern limit it passes into a distinct greyish-green amphibolite, in which considerable mica has been developed. Under the microscope it is found to be composed chiefly of plagioclase and hornblende, and thus to be classed with the diorites, but it evidently was originally a diabase, as a well marked ophitic structure is still apparent. The augite originally present is almost wholly converted into hornblende, while during this process of uralitization, as is usual, a considerable quantity of epidote has been developed. It is a straw-yellow colour, exhibits strong pleochroism, and has often fairly good crystallographic outlines, although occurring mostly in irregular grains and patches associated chiefly with the hornblende.

The process of uralitization is here very interesting. The augite alters first into a compact green trichroic hornblende. Where it has suffered most from dynamic action a fibrous variety of hornblende (actinolite) has resulted, which has in turn decomposed into chlorite that still preserves much of the pleochroism of the hornblende. Between crossed nicols the matted aggregates of scales of chlorite show collectively the deep-blue polarization-colour so often exhibited by it. Much of the plagioclase is remarkably fresh for such a decomposed rock, but a great deal of it shows a somewhat advanced saussuritization, the resulting epidote, zoisite and sericite being especially abundantly developed where the rock has been most squeezed. Ilmenite occurs in aggregates of small grains which are each surrounded by a rim of leucoxene. Quartz, although present, is not at all abundant. Where pressure has been greatest the rock passes into a typical hornblende-schist or amphibolite. The ophitic structure cannot be detected under the microscope, while pressure has caused the breaking up of the original bisilicate individuals, so that they are now represented by many small shreds and fragments, arranged with a more or less parallel alignment. A great deal of epidote has been developed, while the ilmenite originally present has been almost converted into a brownish sphene, now seen in irregular grains or aggregates of grains scattered through the rock. Associated with and apparently caught up in this eruptive are certain small patches of sericitic and epidotic slates, while on one portage (the tenth from Lake Timiskaming) an interlamination of light and dark-grey quartzite with red jasper and magnetic iron ore occurs, the whole running parallel with the foliation of the enclosed rock, N. 20° E., and dipping N. 70° W.< 70°.

Above Mann island the seventh portage from the lake is merely a lift over a rocky islet to avoid a small rapid in the river. A short distance farther up the next or eighth portage is reached. This is but a short carry across to a small lake to the northeast of the river and a short paddle across this brings us to the outlet at its east end. Another short portage along the bed of this outlet comes out again to the main stream. Above this is a sharp turn in the river, its direction changing abruptly to a southeasterly bearing. The canoe-route again leaves the main stream below this elbow, a very rough portage on the southeast side leading to a narrow lake about half a mile in length. The next portage, divided into two carrys by an intervening pond, counts as the eleventh and twelfth, leading back to the main river. The route thus follows a narrow valley running parallel to the river, avoiding a very rapid stretch of river, with a total fall of about fifty feet. The direction of the river here coincides with the foliation of the hornblende-schists. The thirteenth portage is on the east side of the stream, and is sometimes called Cypress portage. It is over half a mile in length and is occasioned by a rapid with a fall of over twenty feet.

Toward the head of Cypress portage the uralitic diabase, largely changed into a rather typical hornblende-schist, is penetrated by small stringers composed chiefly of flesh-red feldspar and grey quartz, with occasional small fragments of hornblende. The connexion of these small apophyses of granitic material with the larger parent mass of hornblende-granite-gneiss exposed farther east was clearly established, and these lenticular patches of quartzo-feldspathic material become more abundant as the vicinity of the granite-gneiss is approached. The rock contains considerable secondary biotite, developed chiefly along the planes of shearing, and this, in conjunction with lighter feldspathic bands, produces a very distinctly foliated rock, The foliation dips westwards at a high angle, generally about 50°.

The same rock continues, with the interfoliation of lighter and darker bands, across the fourteenth or Maples portage, at the head of which the course of the river turns rather abruptly to an easterly direction while the width is increased to a quarter of a mile. The dividing line between the hornblende-schists-gneisses crosses this lake-like expansion obliquely. Although the actual contact is not exposed the two rocks are seen within a very short distance of one another, both striking toward the northwest, while the dip of the foliation is to the southwest at an angle of about 50°. The junction between the two is evidently one of intrusion, the granite-gneiss piercing the amphibolite in the form of the small interfoliated pegmatite streaks and patches above described, and it appears that the irruption of the hornblende-granite-gneiss was the cause of the foliation and alteration of inceptive diabase, producing the hornblende-schist.

The granite-gneiss just alluded to is a reddish, very distinctly foliated rock, the foliation being determined by the more or less parallel disposition of the fragments and individuals of hornblende. The thin section shows the rock to be composed essentially of orthoclase, microcline, hornblende and quartz, with sphene, epidote, zircon and apatite as accessory or accidental constituents. Much of the orthoclase occurs as irregularly shaped individuals or phenocrysts embedded in a finer-grained mosaic composed of broken up fragments of feldspar and quartz. These smaller fragments very often assume the microcline habit, which is evidently the result of pressure. The larger orthoclase individuals show considerable alteration, especially in their central portions, and although in some cases they exhibit tolerably sharp and perfect crystalline outlines they are usually more or less jagged, owing to the breaking up of their borders to form part of the finer-grained mosaic. The hornblende is dark green, trichroic, and occurs in irregular shreds and fragments having a marked parallelism. The sphene is deep brown in colour, and occurs in characteristic wedge-shaped crystals. The epidote is evidently of secondary origin, and is present in irregular grains and masses of a deep straw-yellow colour and strong pleochroism. Zircon and apatite are in small acicular prismatic crystals. The reddish colour is imparted by the presence of iron-oxide, which fills the cleavage-cracks of the feldspar as well as the minute fissures present in the rock itself.

This rock continues as far as Lac des Quinze, but near the lake it becomes coarser in texture and more highly porphyritic, the reddish crystals of orthoclase being frequently as much as half an inch in diameter. The foliation is rather obscure, but on the lake itself is more evident.

The fall overcome by the last or fifteenth portage before reaching the lake is about ten feet.

Lac des Quinze takes its name from the river. The general summer level of this lake, as determined by the mean of a large number of aneroid readings, is 848 feet above sea-level. The area of the lake is approximately forty square miles. A considerable portion of the northern part of the lake is, however, not represented on the accompanying map. There is a Hudson's Bay trading post on the lake, known as Long point, while lumbermen now at work in the country near Lake Winnowaia or Expanse, a little to the east of the present map-sheet, have several farms or clearances, and depôts for supplies.

The main body of the lake extends to the southeast from the outlet for a distance of about eight miles, with an average width of a little over a mile. A second, generally about a mile wide, runs northward for a like distance from the outlet and then divides into two bays, which continue with the same general direction for about three miles farther, the more westerly of the bays being the one followed in going to Lake Abitibi. About two miles to the east of the north arm a second narrow inlet extends to the north for about three miles. From the southeastern extremity of the main body of the lake two arms branch off. The larger one runs to the northeast for about fifteen miles, gradually tapering to a point, where it receives the Upper Ottawa. The second arm runs to the southward for about five miles, and at its southeasterly corner reaches the western terminus of the road from Baie des Pères. A new road from Lake Timiskaming to Lac des Quinze, to the north of the River des Quinze, starts from the foot of the first rapids, but is not yet completed.

The several arms of the lake have all been eroded in a direction corresponding with that of the foliation of the gneissic rocks, and evidently represent the more schistose and least resisting belts of these rocks. The prevailing rocks are grey granitic and dioritic-gneisses, the latter containing usually a considerable proportion of biotite in addition to the hornblende, and with an increase in the abundance of the bisilicates, passing into an almost black, glistening amphibolite, in which the schistosity is always well marked. Quartz is present in considerable quantity, particularly in certain bands, and epidote was also noticed as a somewhat abundant constituent. At several points on the lake massive crystalline diorite was observed. The gneisses have a well marked foliated structure, the inclination of this foliation varying from 30° $<$ 45° in a westerly or northwesterly direction.

LAKE KIPAWA.

The name Kipawa means, freely translated, 'a very narrow passage between steep rocks,' and refers to the presence of a gorge in the northern part of the lake, now generally known as the 'Canal.' The lake is very irregular in form and full of islands. In general the lake may be described as filling several valleys approximately parallel to that occupied by the southern portion of Lake Timiskaming. The general trend of these valleys, like that of Timiskaming, cuts across that of the foliation of the gneissic rocks, except in those portions of the southeast of Roche à Corbeau and the Beauvais narrows, where the main direction of the lake corresponds rather closely with the foliation of the adjacent gneisses. The greatest length of the lake, from Chemagan bay on the north ,to the portage leading out of Jeanbeau bay on the south, is almost thirty-two miles, on a line bearing S. 12° E. It may be said to be divided into two main portions occupying an approximately parallel position, each, however, branching off in bays and arms in various directions. These two larger portions are connected about the centre by a few comparatively narrow channels. The portion to the southwest, extending from the outlet at the northwest end of Sandy Portage bay to Jeanbeau bay, measures twenty-seven miles in a direction of S. 38° E.; while the large body of water to the northeast, reaching from the northwest end of Taggart bay to the outlet of Hunter lake, a distance of twenty-eight miles, has a general trend of S. 42° E. The area of Lake Kipawa, including the islands, is nearly 120 square miles. Its height above sea-level varies from 876 to 886 feet. The Kipawa river, its natural outlet, is a crooked and rapid stream which enters Lake Timiskaming a little over six miles below the Montreal river. The lumbermen have, however, built a dam across the Kipawa at the northwest end of Sandy Portage bay, thus raising the water-level. The rocky obstructions between the southwestern part of Lake Kipawa and the ponds at the headwaters of Gordon creek having been removed, a large portion of the Kipawa waters now discharge by this artificial channel. In this way the "drive" for logs is much shortened and the water held back until required.

The greater part of the shore-line of the lake is somewhat high and rocky, the surface being often strewn with large boulders, chiefly of the underlying gneissic rocks.

There is little level land, although clearances have been made and farms cultivated in connexion with lumbering. Most of the white pine of first quality has been cut, but the shores are still beautifully wooded.

Of the very numerous islands McKenzie and Karl islands are the largest, the former being a little over five miles in length and averaging about two miles in breadth, while the latter is scarcely half this size, measuring a little over two miles in length by about a mile and a half in width.

The "Canal," already mentioned as giving its name to the lake, is a picturesque feature, being a narrow gorge about a quarter of a mile long with perpendicular walls of gneiss, situated about a mile northwest of Mackenzie island, and it leads into a couple of small lakelets or expansions.

The rocks so abundantly exposed along the shores and islands of Lake Kipawa are remarkably uniform in composition and macroscopical characters. They are typical examples of "gneisses," being, as a rule, very distinctly and evenly foliated, and exhibiting darker and lighter-coloured bands of more or less basic character. The more acid bands are usually of greyish, reddish grey or flesh-red colour; while the more basic bands are of varying shades of darker grey, becoming almost black in certain instances. The lighter-coloured phases are, perhaps, the most abundantly represented, and besides occurring as interfoliated bands associated with more basic material, these in themselves constitute the greater portion of somewhat important and extensive rock-masses. Under the microscope they are seen to contain orthoclase as the prevailing feldspathic consituent, and biotite as the principal and often the only ferromagnesian mineral. They must, therefore, be referred to as biotite-granite or granitite-gneiss. Besides these microcline is usually abundant, together with some plagioclase (usually oligoclase). A large amount of quartz likewise accompanies the feldspar. The biotite is, as a rule, fresh and of a deep brown colour, occasionally showing alteration to chlorite. A little muscovite (most of which is of secondary origin), sometimes occurs, but not in sufficient quantity to characterize the rock. Besides these, smaller quantities of epidote, sphene, sericite, chlorite, apatite, zircon, magnetite, and sometimes allanite, are usually present.

Occasionally somewhat darker and more basic portions are seen to contain a compact dark-green trichroic hornblende in addition to the biotite, the rock thus becoming a hornblende-granitite-gneiss. These portions are usually of a dark-grey colour, and show a very marked abundance of the coloured constituents.

The very dark-grey, almost black varieties, in which but little of the lighter-coloured minerals can be macroscopically detected, often show plagioclase as the prevailing feldspar, while biotite is replaced by hornblende, the principal ferromagnesian mineral, although biotite is likewise almost invariably present. The constituent minerals are essentially the same as those present in the more acidic phases, differing only in their relative proportions.

The structural relations of these rocks show that they form integral and inseparable portions of one complex, produced by differentiation during the slow cooling of a magma of more or less heterogeneous composition.

At the head of Gordon creek, and in the vicinity of Kipawa post-office, (formerly Norcliffe), the gneiss is very distinctly foliated, the strike being about S. 55° E., the dip S.W.< 10° to 20°. The thick massive bands in the high bluff to the north of the railway terminus, representing the more acid portions of the rock, are granitic both in appearance and composition. Feldspars, both reddish and greyish, are present as well as quartz, and a very sparing quantity of mica. The quartz, besides being present in grains and areas distributed throughout the rock, also occurs as veins and masses, evidently representing the most acid form of the prevailing pegmatite.

On the northeast shore of the largest island of the group, situated about a mile east of Kipawa post-office, are good exposures of light-grey and pinkish-grey quartzo-feldspathic gneiss, alternating with darker bands which contain hornblende in addition to the more usual biotite. The strike is east-and-west, with dip to the south<35° to 45°. Along the shore the basic bands have been weathered out more easily than the acid ones.

Farther to the southeast, toward Jeanbeau bay, the gneiss varies in strike from S. 50° E. to S. 60° E. with a dip to the northeast <20° to 30°. North of Gordon creek the foliation of the gneiss corresponds rather closely with the trend of the shore-line, dipping to the northeast at varying angles. At Greenorton bay the schistose gneiss is very basic and contains hornblende in addition to the biotite. This rock also holds garnets and vein-like bands of smoky quartz. At the foot of Gibson bay the gneiss is of the common light-greyish granitite variety. On the south shore of Bryson island there are good exposures of a light-grey granitite-gneiss, the foliation being much contorted.

Beauvais narrows cuts the foliation of the gneiss at a considerable angle, the strike being S. 65° E. with a dip to the northeast< 15° to 25°. On the south shore of Smith bay exposures of hornblende granitite-gneiss show the constituent feldspar much decomposed and a large part of the biotite altered to chlorite. At Fowler point a knoll rising about forty feet above the surface of the lake is composed of a fine-grained almost black quartz-mica-diorite. This rock contains irregular patches and stripes of a much more acidic gneiss, light flesh-red in colour, which seems to contain feldspar, quartz, biotite and garnet, with occasionally some muscovite and epidote. Near Edward depôt, on the north shore of Smith bay, the granitite-gneiss is as a rule very acidic, containing only small quantities of biotite. At Somerville point the gneiss is a reddish granitite much weathered and showing what appeared to be a very local strike of N. 40° E. The southwest shore of the lake opposite Sunnyside post-office is composed of reddish granitite-gneiss, generally striking with the trend of the shore, but sometimes showing many local twistings. At Turtle portage the usual granitite-gneiss shows a beautiful curve in the foliation, the strike gradually turning from N. 80° E. to S. 60° E., with a prevailing southerly dip. At Hunter Lodge narrows and on Hunter lake the gneiss strikes about S. 60° E., dipping in a southerly direction.

Along the south shore of McLaren bay the gneiss is usually of a light-grey colour, rather fine-grained, micaceous and granitic in appearance, being tinged with iron-oxide. It usually shows a distinct though imperfect foliation on account of the comparative scarcity of bisilicate material. The strike is N. 82° E. and the dip to the south. Microscopically this is a typical holo-crystalline granitic rock or granitite-gneiss, consisting essentially of orthoclase, quartz and biotite, with apatite-zircon, sphene, a very little magnetite, much microcline and some plagioclase, (oligoclase) small quantities of secondary muscovite and epidote are also present.

At the south end of an island immediately east of McKenzie island there are exposures of the ordinary flesh-red granitite-gneiss. On the northwest shore of McKenzie island the hornblende-granitite-gneiss seems to change in strike from N. 20° E. to N. 50° E., thus conforming with the trend of the shore-line, while the dip is to the southeast at varying angles generally about 60°. At one point a vein of quartz (pegmatite) varying in width from six inches to two feet cuts the gneiss, of which it contains fragments. The gneiss here is well foliated and often locally twisted. The gneiss composing the cliffs on either side of the "Canal" contains a considerable quantity of quartz and is much weathered and stained. It has a strike of N. 65° E. with southerly dip $<$ 80°. At the south end of Campbell bay the strike of the gneiss is north 62° east. A thin section of a specimen obtained from the western shore, about two miles south of the entrance, representing the most basic bands, showed the rock to be a quartz-mica-diorite-gneiss. The rock is nearly black, very evenly and distinctly foliated and exhibits glistening cleavage-surfaces along the planes of foliation. Exceptional bands are of light pinkish-grey colour, feldspar being the predominant constituents.

Microscopically, this rock is composed of plagioclase, orthoclase, microline, quartz, hornblende and biotite, with epidote, sphene, apatite, zircon and some pyrite, more or less altered to limonite.

On the west shore of Karl island, as well as on the island lying to the southwest, the gneiss shows the usual variation from greyish to reddish, with interfoliated darker bands in which the biotite is more abundant. The strikes vary from N. 64° E. to N. 67° E., with dip to the south < 60° to 70°.

At one place on the north shore of the lake, half a mile north of the northeast point of Karl island, a very massive and coarsely crystalline porphyritic diorite is associated with the ordinary greyish granitite-gneiss. This rock is of a dark-green colour when fresh, but near the surface is decomposed for a depth of nearly two inches, the decomposed layers being much lighter in colour. Large phenocrysts of deep-green hornblende, some of which are an inch or more across, and most of which possess tolerably well defined crystalline outlines, are developed in a coarse-grained groundmass composed almost wholly of allotriomorphic individuals of dark-green trichroic hornblende, the small and irregular interspaces being filled with feldspar and quartz. Much of the hornblende includes dark schillerization products. The decomposed layer near the surface shows the somewhat abundant development of epidote at the expense of the hornblende, giving the prevailing yellowish-green colour to this portion of the rock. The whole exposure measures about fifteen yards long by twenty-five yards wide and is surrounded by the greyish granitite-gneiss, while several dikes of pegmatite varying from a quarter of an inch to six inches in width cut the diorite.

In the northern portions of Hay bay the prevailing rock is the ordinary granitite-gneiss, the strike of which varies from N. 60° E. to N. 70° E.

The rock exposed on the shores and islands of the bay running towards the outlet, the northwestern portion of which is generally known as Sandy Portage bay, is the usual reddish and greyish biotite-granite-gneiss or granitite-gneiss . The strike varies in general from N. 50° E. to N. 60° E., while the dip is to the northwest at high angles, generally varying from 65° to 85°. Near the outlet the strike turns more to the north, the foliation in this vicinity running about N. 40° E., while the bands are nearly if not quite vertical. At one or two points extremely basic portions of the gneiss were seen to be highly hornblendic, thus passing into quartz-mica-diorite.

MATTAWA RIVER.

The term Mattawa was first applied to the confluence of this river with the Ottawa. The river has also been known as the Petite or Little river, while to the Indians it was formerly known as the Tessouacsipi. It is really a succession of large deep lakes united by comparatively narrow and shallow rocky stretches. The total distance from the Ottawa to the western end of Trout lake, in a straight line, is about thirty-six miles, but following the river this is increased to forty miles. The direction is in general nearly east-and-west, following a continuation of the main valley occupied by the Ottawa below the confluence of the two streams. In ascending the Mattawa rapid water is encountered almost at once, the stream flowing over a shallow bouldery bed. This, together with a small rapid, a little over a mile above at the outlet of Boom lake, gives a fall in the river of about two feet.

Boom lake, the first expansion reached, is about a mile and a quarter long, and not over a quarter of a mile at its greatest width. At the upper end of this lake the river is contracted in two places to a width of less than a hundred feet and a fall of nearly twenty feet is occasioned by the Plein Chant rapids. Plein Chant lake, at the head of these rapids, is five and a half miles in length. The widest portion is near the eastern end, where it is about thirty chains, but this gradually diminishes westward, until, near the upper end, it is not more than three or four chains wide. In the widest portion a depth of over two hundred and eighty feet was found.

Between this lake and Lac des Aiguilles, the next expansion, the distance is a little over two miles, and four rapids intervene, with alternating stretches of still water; the combined fall is eighteen feet. The three largest rapids are known in ascending order as Les Epines, La Rose and Des Roches or Des Aiguilles. The Amable du Fond river, the largest tributary of the Mattawa, enters from the south side a short distance above the second rapid. Lac des Aiguilles, which is a little over a mile long and a quarter of a mile wide, is separated from the next succeeding stretch of river, lying parallel to it on the north side, by a rocky bar known as Les Aiguilles islands. The three narrow rocky channels formed by these two islands, even at high water, barely afford a passage to loaded canoes. The eastern one constitutes the main route, and a small rapid at this point shows a descent of a few inches. Above this is a long stretch of deep water that gradually diminishes in width. The river throughout this distance of two and a half miles is flanked on either side by almost perpendicular walls of gneissic granite.

At the end of this stretch the upward course of the river changes sharply to a southerly direction for about two miles, and presents a series of rapids with intervals of deep water, the total fall being fifty-five feet. The Chute des Paresseux, where the water falls thirty-four feet, is the first and largest of this series. Pimisi or Eel lake, (sometimes also called Penice bay and Moon lake), above these rapids, marks another change in the course of the stream, which from this place to the head of Talon lake trends northwesterly. Between Eel lake and Talon chûte the river flows for three-quarters of a mile through a narrow rocky cañon enclosed between perpendicular walls of granite. Talon chûte is the greatest single fall on the whole river, the water descending forty-three feet over a rocky ledge composed of massive flesh-red gneissoid granite. The main channel is on the north side, but in addition there is another though much smaller parallel passage. The downward extension of this passage is continued in a deep gorge which connects with the main channel a short distance below the falls, the whole apparently representing the erosion of a band of crystalline limestone that here occurs. About half a mile below Talon chûte a small rapid occurs with a descent of less than a foot, and a short distance above it is Talon lake. To the left, on entering the lake, a large bay runs westward for about three miles, Kabiskaw bay, at the western extremity of which an important tributary (Kabiskaw creek) enters, forming the outlet of Nasbonsing lake, a large and irregular sheet of water situated in the southern part of the township of Ferris.

Talon lake lies northwest and southeast, is about seven miles long and has in general a breadth of almost three-quarters of a mile. The shores are generally bold and rocky, although occasional small sandy flats occur. The general depth may be said to vary from fifty to one hundred feet, but in occasional spots a depth of two hundred feet and over was met with.

The connecting stream between Talon and Turtle or Lower Trout lake, the next expansion in the river, is about four miles. The stream leaves Turtle lake about a mile from the eastern extremity. It is shallow, rocky and rapid with some small intervening ponds of deeper water. Turtle lake lies nearly east and west and is about four and a half miles in length and not more than half a mile in width. Thence an ascent of barely a foot occurs, in a short channel, to Trout lake, at the summit. This is eight and a half miles in length with a greatest breadth, near the upper end, of about two miles. It is often over 200 feet deep, and the shores are rough and rocky. To the north of the lake a range of hills from three to four hundred feet high extends with almost unbroken continuity to the mouth of the Mattawa river and thence northward and northwestward up the valley of the Ottawa.

The extreme west end of Trout lake is only about three miles distant from Lake Nipissing, and the neck of land separating the two lakes is in general very level. The canoe-route usually followed to Lake Nipissing leaves Trout lake in a bay running to the south near its western end. The first portage runs over a ridge of sand. The Rivière de la Vase is then utilized all the way to Lake Nipissing, a distance of a little over six and a half miles. This small stream runs through low and often marshy ground most of the way, entering Lake Nipissing about six miles southeast of North Bay.

The land in the immediate neighbourhood of the Mattawa river is generally rocky, barren and unfit for agriculture. A short distance from this river, however, in the townships of Papineau, Calvin, Bamfield and Ferris, considerable areas have been cleared, and good progress has already been made in the settlement of these townships.

The rocks exposed along the Mattawa are for the most part massive reddish granitite-gneisses, the strike of the foliation running in a series of widely undulating curves in a general east and west direction with a prevailing southerly dip $< 35°$ to 65°. Crystalline limestone is very sparingly present in assocation with these gneissic rocks, and wherever noticed the evidence seems to show that it has been caught up in the gneiss during the irruption of the latter. On the south shore of Talon lake, as well as in the southern channel at the falls, at the outlet of this lake, the crystalline limestone was found in association with a very massive indistinctly foliated granitite-gneiss, the intrusion and latter age of the latter being apparently clear. Near the western end of Nasbonsing lake the rock is a light-reddish granite-gneiss composed chiefly of feldspar, with a small proportion of greyish quartz and a little black mica occuring in isolated areas of aggregated scales, together with numerous small garnets. The strike is to the northwest with a dip to the southwest, generally at a high angle. Near the eastern end of the lake the gneissic rocks present are more highly differentiated and occur in irregular curving bands which have a general strike curving gradually around from east to northeast.

On Trout lake the granitite-gneiss occurs in reddish and dark-coloured bands which have a prevailing direction of nearly east and west, gradually bending round to the northwest in the western part of the lake, while the dip is to the south $< 45°$ to 65°.

Lake Nipissing.

This important lake has an area of 345 square miles, and is wholly surrounded by Laurentian rocks. Its main length is east and west, and its greatest length, from the shore at East bay, near Callander station to the western end of Bear bay (west arm), is sixty miles; while the greatest width, from Beaucage bay on the north to the mouth of the South river, is sixteen miles. The elevation above sea level, at different seasons, varies from 642·2 to 649·5 feet. The northern and eastern shores are in general low and for the most part present sweeping beaches of sand, separated by rounded points of rock. The water, for a considerable distance from the shore, is shallow. The west end of the lake has an irregular coast line with long arms and bays extending, and rocky islands. A great number of these islands strew the more open water outside, running in long lines, more or less parallel in direction with the peninsulas or points which divide the bays from one another. The islands, generally small, are sometimes several miles in extent. The southern shores are bold and rocky and the water is deep even in their immediate vicinity. The whole of the eastern end of the lake is wide and exposed, containing only two small groups of islands known as the Manitou and Goose islands.

The western end of the lake consists of four principal bays or arms, separated from one another by rocky promontories, their continuation towards the deeper water in the central portion of the lake being marked by the occurrence of long lines of islands and reefs. The most northerly inlet, McLeod or Goulais bay, has an almost direct north and south trend. It is about four miles in length by nearly two in breadth and lies immediately west of the marshy delta of Sturgeon river. The water in this bay is very shallow. A rather narrow and crooked channel, however, exists near the eastern shore, but is navigable only for very small steamers or tugs. Immediately southwest of this bay, and separated from it by the rocky peninsula ending in Goulais point, is another arm of the lake, divided to the west into two subsidiary bays, known as Northwest bay and Middle West bay respectively. Northwest bay is over four miles in length, with a width rarely exceeding a quarter of a mile, and having the general direction indicated by its name. Gradually tapering westwards it receives a small stream that drains some marshy lakes situated in the northwestern part of the township of Macpherson. Middle West bay is much less important, being only about two miles in length, and at the west end receives a small tributary known as West river, that drains the southern part of the township of Macpherson.

Of the indentations extending to the west, however, the largest is known as the West arm or Bear bay. The general trend of this extension is nearly east and west. An inspection of the accompanying map will convey a good idea of the close dependence of topographical outline on the strike of the foliation of the enclosing gneissic rocks. In many instances abrupt changes in direction are encountered, but these follow correspondingly sharp curves in the lines of foliation and cleavage. The width of the bay is very variable, alternately contracting into narrow straits only a few chains in width and opening again into wide expanses generally crowded with islands. In the eastern portion, for a distance of nearly eight miles, the average width is nearly two miles. The bay gradually narrows towards the west end where it receives the waters of a small stream, draining several important expansions to the west.

Several important streams enter Lake Nipissing. The largest is the Sturgeon river, draining about 3,000 square miles of country to the north and west, and joining the lake in the midst of a large marsh on the north side. This low tract of land, forming a delta, has been produced by the gradual accumulation of detritus brought down by the stream.

The Little Sturgeon, or Silver river, enters the Great North bay with a swift and deep current, being navigable for canoes, without interruption, for a distance of a little over two miles from the lake, where the stream becomes very small and rapids occur. The general course is at first nearly north, and the upper course is nearly northeast, to its sources in the southern part of the township of Blyth. Duchesney and Chippewa creeks enter the lake in the vicinity of North Bay. The Rivière de la Vase, or Little Mattawa, flows into the lake about five miles southeast of North Bay. Other important tributaries enter the lake from the south, but these are beyond the boundaries of the present map. The Veuve river is an important stream which enters the west side of McLeod bay, draining a large tract of land, the sources extending westward almost to the Wanapitei river.

Several important islands and groups of islands occur, lying out towards the middle of the wide eastern portion of the lake. The most important of these is the group named the Manitou islands. These are five in number, situated five miles southwest of North Bay. The largest is known as the Great Manitou or Newman island. It is an irregular triangle in form and about a mile across. McDonald island, the next in size, is about half a mile in length from north to south but only a few chains in width. The other three islands are much smaller.

The Goose islands lie toward the centre of the open part of the lake, about six miles west of the Manitou islands, and about twelve miles west-southwest of North Bay. The largest island is known as the Great Goose, and is nearly a mile long with a trend of east and west. To the west and northwest of these there are about a dozen smaller ones, some of which are merely rounded hummocks of rock.

The general aspect of the western end of Lake Nipissing is rocky and desolate. In many cases the sparse soil overlying the rarely concealed hummocks of rocks affords substance to a rather thin and scrubby growth of red pine, while the level spots are for the most part occupied by vast marshes, but some small tracts of level land occur along the banks of some of the tributaries, notably the one situated on the south side of Bear bay near its entrance. The northern shores of the lake, however, border large areas of cultivable land. The rocks are generally well exposed, especially in the western and southern portions of the lake. They include the prevailing varieties of granitite-gneiss and hornblende-granitite-gneiss, the former being the prevailing type. These are cut by dikes and masses of pegmatite presenting the usual characteristics.

The Manitou islands are composed of a rock which is remarkably uniform in composition and appearance, being a medium-textured reddish gneiss, that has evidently been subjected to intense dynamic action. It has a rather indistinct blotchy appearance, due to irregular bands of chloritic and epidotic material running through it, resulting from the alteration of the bisilicates. The microscope shows that the rock has everywhere been greatly granulated. Its chief constituents are quartz, orthoclase, plagioclase, hornblende and biotite, with epidote, chlorite, calcite, sericite, iron ore and apatite. It is thus a hornblende-granite-gneiss which has suffered great alteration, the feldspar being turbid and full of inclusions of sericite, calcite, &c., resulting from its decomposition. Numerous irregular patches of calcite are scattered through the section. Both feldspar and quartz extinguish very unevenly. Hornblende is the most abundant ferromagnesian mineral present, but it has suffered such extreme alteration to chlorite and epidote as to mask its true characters. Biotite, largely altered to chlorite, occurs intergrown with the hornblende. The section is traversed by numerous cracks filled in with secondary quartz, epidote, iron oxides, &c.

On several of the islands this rock, which has evidently resulted from the crushing of a hornblende-granite, contains large patches of pinkish crystalline limestone; the latter, however, doubtless represents portions of the clastic Grenville series. The gneissic rocks are intersected by dark-greenish dikes of basic material previously described in that portion of the report treating of Post-Archæan eruptives. On several islands small outliers of the Birds Eye and Black River formations are exposed, as elsewhere noted.

Rock exposures are abundant on the Goose islands, showing a medium-grained red granitic gneiss. The foliation is determined by the parallel arrangement of the little bands of biotite. The principal constituents are quartz, orthoclase, plagioclase, microcline and biotite, with small quantities of apatite, zircon, chlorite, epidote, sphene, calcite and secondary iron ore. It is one of the typical biotite-gneisses or granitite-gneisses of the region, evidently resulting from crushing and differentiation of a granitite. The feldspars are exceedingly turbid, being filled with dust-like particles and contrasting sharply with the clear quartz grains. Orthoclase predominates, but plagioclase (albite) is very abundant. Most of the microcline grains observed exhibit a moiré-structure rather than the typical rectangular lattice structure. The biotite shows alteration to chlorite with development of secondary magnetite along the cleavage-planes. Apatite and zircon are both abundant in large well-formed crystals, as well as irregular grains. Numerous skeleton forms are scattered through the section, filled with calcite and a substance resembling leucoxene. Their outlines, sometimes rudely wedge-shaped, are defined by minute granules of a secondary iron ore, which also run along what were originally cleavage cracks. These in all probability represent titanite originally present in the rock, which has undergone almost complete alteration with formation of calcite and ilmenite. Minute granules of epidote are present as the result of the alteration of the feldspars. The rock does not present evidence of having been subjected to an intense degree of pressure, for although both quartz and feldspar have wavy extinction the quartz grains are only slightly cracked and not granulated to any extent.

STURGEON RIVER.

The Sturgeon river,* one of the largest in the country to the northeast of Lake Huron, possessing a drainage area of about three thousand square miles, takes its rise beyond the region covered by the accompanying map-sheets, and close to the sources of the most easterly branch of the Montreal river. From the source to its mouth on Lake Nipissing the river measures about one hundred and forty miles in length, the general course being to the southeast. At a distance of one hundred and twenty-five miles from the mouth the stream is divided into two branches inconsiderable in size. The more westerly of these has never been explored, but the branch which comes from the northeast drains an important chain of lakes forming the well-known canoe-route to Shusawagaming† (Smoothwater) lake at the head of the eastern branch of the Montreal river. Three miles below the forks the river expands to a quarter of a mile in width for a mile and a quarter, forming Paul lake,‡ which is frequently though incorrectly described as the source of the Sturgeon. This lake is about 1,258 feet above the sea. The Sturgeon debouches in an extensive marsh by two channels. The most direct or westerly one is almost completely filled with detritus, while the eastern branch is comparatively deep and navigable even for steamers. Once across the bars the river offers uninterrupted navigation as far as the village of Sturgeon Falls, over four miles from the lake.

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*This river is called "Champlain's river" on Delisle's map of New France 1703.

In ascending the stream the general direction is N. 35° E. for eleven miles in a straight line. This is to the mouth of a tributary coming from the east, known as Smoke river, that drains the southern portion of the townships of Grant and Charlton. In this distance navigation is interrupted by two falls and two rapids. The first of these, Sturgeon falls, is opposite the village of the same name, at the intersection with the main line of the Canadian Pacific railway. Sandy falls is the name of the next, nearly six miles above the village, while the rapids, which occur a couple of miles beyond, generally require to be portaged in the ascent, although they can be run in descending. The portage to avoid this half-mile of broken water is on the west side of the stream.

Near the mouth of the Smoke river the Sturgeon takes a sudden bend, and has an upward direction in a straight line of N. 61° E. for twenty-eight miles, as far as the 'Elbow,' in the township of Janes. Following all the sinuosities of the stream, however, this distance is increased to a little over thirty-six miles. The main tributaries in this interval are from the north, draining large lakes in this direction. The Timagami, which is a very turbulent and rapid stream, is the largest feeder of the Sturgeon, and is the principal outlet of the large lake of the same name. It enters the Sturgeon a little over twenty-three miles above the mouth of the Smoke river. The Tomiko (contraction for Otanacomagosi or Canoe-making) river enters a little over five miles above Smoky falls, deriving most of its water from several large lakes situated in the townships of Gladman and Hammell. The lower portion of the stream, from Tomiko lake to the Sturgeon, is rarely if ever used for the purposes of canoeing. A long portage, to avoid this rough stretch of river, runs northward from the Sturgeon, starting from a point nearly two miles above Smoky falls. It affords an entrance to Cameron lake and thence through Chebogomog lake into Tomiko lake. The upper portion of the river, however, is travelled to reach the numerous lakes situated near the headwaters of the several branches of the stream and thence to the region beyond. Pike river is another feeder, coming from a lake of the same name, situated near the centre of the township of Bastedo.

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†Sometimes also called "White Beaver lake" from a mountain of that name which rises immediately to the west of the lake.

‡The name is given in honour of "Big Paul," a sub-chief of the Timagami band of Chippewa Indians, who has made this lake his headquarters for many succeeding winter hunts.

Between the mouth of the Smoke river and the 'Elbow' the Sturgeon is broken by one fall and five rapids, the latter all situated above the mouth of the Timagami river. The most important of these obstructions is the Smoky falls, where the river descends over a solid barrier of gneiss for more than twenty feet. The portage runs over a small rocky island of gneiss which here divides the river into two channels.

At the 'Elbow' the trend of the river again changes abruptly to a direction of N. 14° W., which course is maintained as far the mouth of the Obabika river, a distance of twenty-two miles increased to thirty-four miles by the bends of the stream. Only a little over a third of this distance is included on the accompanying maps, as far as the mouth of the outlet from Wawiashkashing and Manito-peepagee lakes. The largest tributary in this distance is the Maskinongé river, that reaches the main stream from the west about two and a half miles above the 'Elbow' and drains a number of large lakes, shown on the Sudbury map-sheet (No. 130.)

The Sturgeon river is in general readily navigable for canoes throughout the whole distance embraced in the present map-sheets, although the current is strong nearly the whole way. Between Smoky falls and a point about three miles above the mouth of the Timagami branch (a distance of about twenty-five miles) there is no greater impediment to canoe navigation than the strength of the current. The river, except where contracted at the rapids and falls, varies in width from a little over two hundred and fifty feet near the mouth to about a hundred feet in the township of McNish near the northwest corner of the Lake Nipissing sheet. The depth varies from three to twenty feet, with an average of perhaps ten or twelve feet.

The flats along the river are liable to inundation during the high spring freshets and the actual rise in the water at the several points along the course of the stream may be readily ascertained by a reference to the appended list of elevations.

The river for the most part pursues a somewhat tortuous course through a tolerably level flat of considerable extent, exhibiting numerous sections of a stiff greyish clay overlain by coarse yellowish sand, in the immediate valley of the Sturgeon. Below the Timagami river there are many areas of considerable extent which have been utilized for the settlement and the soil has in general proved productive. Between the mouths of the Timagami and Maskinongé rivers these flats are fewer and less extensive while the country immediately adjoining becomes for the greater part poor and rocky. Above the Maskinongé very little land is available for farming, the country assuming a broken and mountainous character.

The rocks throughout this distance present the usual characteristics of the reddish and dark-greyish gneisses. The dip is towards the south or southeast at an angle of often considerably less than 45°. The exposures in the immediate vicinity are very few, and except in the neighbourhood of falls and rapids are small, consisting chiefly of rounded hummocks protruding from the overlying drift material.

The contact between these rocks and those of the Huronian, occurring to the northeast, crosses the Sturgeon river a short distance above the 'Elbow.' The actual junction is not visible, but exposures of the flesh-red granite-gneiss of the Laurentian and the light greenish compact quartzite of the Huronian occur within a short distance of one another.

THE MONTREAL RIVER.

The Montreal river is, next to the Ottawa and Sturgeon rivers, the largest stream included within the area covered by the present report, draining an area of about 2,500 square miles.

The general course of the river, so far as it is included in the Lake Timiskaming sheet, is southeast, and the length almost forty-seven miles in a straight line. This may be divided into three parts, the first and third of which are approximately parallel in direction, while the second, or short intervening stretch, lies almost at right angles.

The lower portion of the river, from Lake Timiskaming to Mud Lake portage, is now superseded as a canoe-route by the shorter and easier passage by way of Haileybury, Mud and Sharp lakes. There are numerous rapids, and the river, throughout this distance, flows in a narrow valley, generally from 400 to 450 feet deep. Only a few small streams enter this portion of the river, as the highest land occurs in close proximity to the banks on either side. The lowest three miles of the river, before it reaches Lake Timiskaming, are a series of rapids with a fall of 160 feet. At the 'Notch,' near the mouth, the river flows through an extremely narrow channel, with

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See Plate IV.

rocky perpendicular walls, composed of dark-greenish greywacké slate, much jointed and broken. This gorge has a breadth varying from sixteen to thirty-three feet and is a little more than a hundred yards long, with perpendicular walls about forty feet high. The rapids above referred to are overcome by a portage about three miles long.

For about six miles above this portage the river is crooked, with a fairly gentle and uniform current, its channel being cut through a narrow plain of stratified drift material. There are only occasional outcrops of rock, and these show a comparatively fine-grained arkose, forming the transitional beds upward, from the greywacké and slate to the quartzite grit that characterizes the summits of the hills extending westward to Bear lake.

Three rapids occur in the next stretch before Fountain fall is reached, the total fall in this part of the river being over thirty feet. The rock, wherever exposed, is a dark-green somewhat coarse diabase or gabbro, the feldspar, especially in the coarse phase, being frequently of a reddish colour. Fountain fall has a sheer descent of twenty feet over an outcrop of breccia-conglomerate. Ragged chute is situated a short distance above, and has a fall of about thirty feet. The hills on either side of this wild rapid rise precipitously from the river, and the portage, which is situated on the northeast bank, runs over a very high and steep hill. The rock exposed is the usual breccia-conglomerate, showing a dark-green chloritic matrix which is often present in comparatively small proportion, in which is embedded an abundance of fragments of feldspar, granite and diabase. About a mile above Ragged chute the slate is superimposed upon the conglomerate, dipping S. 70° N. $<$ 20°. Two more rapids of considerable dimensions occur in the spaces between Ragged and Hound chutes, having a combined fall of thirteen feet. At the latter place the waters of the river make a clear leap of twenty-five feet, over an outcropping ledge of diabase. From the head of Hound chute to Mud Lake portage the banks on either side of the stream, and especially those on the northeastern side, exhibit perpendicular cliffs composed of diabase, greatly resembling and co-extensive with a large mass which reaches the west side of Lake Timiskaming, there forming the cliffs known as the Manitou and Devils Rock. The current in this interval of nearly five miles is very swift, showing a total fall of about eight feet, but with no distinct rapids.

Immediately below Mud Lake portage is a high hill of diabase that rises precipitously from the water on the northeast side, while a short distance above, on the opposite side, smaller elevations composed of similar rock were noticed in close proximity to the stream. In the vicinity of the first rapid above Mud Lake portage the banks are again high and rocky, composed of the coarse diabase or gabbro with much flesh-red feldspar, giving it somewhat the appearance of a basic granite. A small rocky island about twelve chains below the rapid shows this diabase to possess a very perfect series of jointing planes with a direction of N. 50° E. and dipping S. E. <70°. The strike of these planes corresponds closely with the trend of the stream at this point and may have been the cause of its direction. The rapids, which are very strong, have a fall of seven feet, and are caused by a barrier composed of outcroping ledges of the diabase aided by an accumulation of loose boulder material. There are no exposures of rock between the head of these rapids and Bay lake, while the river, between the two other intervening rapids, is marked by the occurrence of comparatively wide lake-like expansions, which in places show a considerable current.

Bay lake, known to the Indians as Pakeegama or Mattagamashing, occupies a rather deep depression in the rocky plateau, being bounded, especially on the southwest side, by high rounded hills of slate and quartzite. It runs in a northwest and southeast direction, with a length of seven miles and an average breadth of a little over a quarter of a mile. A large bay near the northwestern extremity runs in an easterly direction for about two miles and a half. The portage from Loon lake, on the road to Timiskaming, reaches the northeast corner of this bay, while the Hudson's Bay Company's post is situated on the point on the northwest shore of the lake near the entrance to Portage bay.

The southwestern shore, near the southwestern end of Bay lake, shows excellent exposures of well banded and evenly jointed greenish-grey slates, while the northeastern shore in this direction is low and covered with thick green bush. About a mile and a quarter north of the outlet the slates are overlain in comformable sequence by the yellowish-green quartzite-grit, the whole having a northwesterly dip < 5° to 12°. The slate as usual shows a gradual transition through a more massive slate into a greywacké or feldspathic sandstone, which merges upward into the comparatively coarse-grained arkose sandstone or quartzite-grit that rises into hills varying from 250 to 300 feet above the lake, in places forming precipitous cliffs of considerable height.

A specimen of this rock was examined by the late Prof. G. H. Williams and was taken to represent the transitional portion near the immediate junction between the coarse greywacké and the quartzite or arkose. The small hand specimens showed a banded coarse and fine conglomeratic sandstone or greywacké. The coarser portion of the specimen presents the ordinary characters of the prevailing quartzite-grit, holding good sized fragments of quartz both angular and rounded in outline, embedded in a moderately abundant sericitic matrix. The finer-grained portion, which has a somewhat darker hue, is a rather typical greywacké, showing 'an aggregate of angular and subangular quartz grains with some feldspar. Between these grains much chloride has been developed, which, together with the magnetite present, gives the dark colour to this layer.'

This quartzite, as usual, occurs in very thick and massive beds and the dip cannot be made out with any certainty except in a few places. It is exposed all along the southwest shore of the lake as far as the inlet and forms the southwestern portion of the point that separates Portage bay from the main body of the lake. Farther up the river the rock is underlain, first, by a massive brownish greywacké or slate, exposed a short distance below Pork rapid, and next, in descending order, by the well banded greenish slates, dipping S. 55° E. $< 10°$ to 15°, which continue as far as and a little beyond the inlet from Lady Evelyn lake. The structure is, therefore, that of a somewhat shallow syncline, the basal bed being represented both by the banded slates exposed in the southeastern part of Bay lake and those occurring in the vicinity of the outlet from Lady Evelyn lake, the overlying quartzites resting in the trough thus formed.

The point on which Bay Lake post is situated is composed of coarsely crystalline diabase or gabbro, the feldspar frequently possessing a distinct flesh-red colour. The massive and rounded exposures of this rock are cut by irregular ramifying dikes, composed of a fine-grained pale-greyish or pinkish aplite. This basic irruptive forms the shores of Portage bay, as well as the northeastern part of the point separating this bay from the main body of the lake. To the northwest of the lake it continues for a considerable distance inland, forming a series of high, though rounded, hills in this district, while to the east, as far as can be learned from the occasional outcrops, it is continuous with the mass which forms the southern part of Sharp lake, extending as far as the western shore of Lake Timiskaming.

Between the head of Bay lake and the head of Lady Evelyn lake, (Mattawapika), the river is in general a fine, wide stream, with occasional short stretches of swift current. Pork rapid, (Kokooshbuwatik), has a total fall of nearly seven feet, the portage being on the southwest bank. The northeastern banks of the river are low, and the country for many miles is flat and swampy. On the southeast side in that direction there are only occasional low rounded exposures of the greywacké and slate, and these are situated some distance away from the stream, forming a series of rounded hills. Between the

Mattawapika and Round or Mountain lake the river is, as a rule, wide and navigable, with only two interruptions by rapids. One of these is a little over a mile and the other about four miles below Round lake, the portage in both cases being on the northern or north-eastern bank of the river. The combined fall of these two rapids is about eight feet, the upper one being the larger with a descent of five feet.

The shores in the vicinity of the Mattawapika show exposures of a well banded slate which dips S. 55° E. < 10° to 15°, and continues for about a mile above this point, where it is interrupted by a mass of diabase or gabbro, which, on the southeast side, rises into a series of precipitous hills. This rock may extend across the stream to the northward, but any hills on this side are much lower and less pronounced, and are, therefore, more likely to be underlain by the greywacké slate. This mass of diabase extends to within a quarter of a mile of the outlet from Mocassin lake, and is an extension northward of the mass of similar rock which forms the western shore of the last stretch of Lady Evelyn lake. To the northwest this diabase is replaced by the quartzite grit or arkose which forms smaller and less conspicuous eminences extending northward and inland for some miles; while to the northeast the general surface outline would seem to indicate its continuous presence as far as the southeastern extremity of Indian lake, although no exposures could be seen. The rock is the usual greenish or reddish-grey, coarse arkose, so prevalent throughout this district. A specimen of this rock was examined by the late Prof. G. H. Williams, who says that 'it shows an even-grained mixture of somewhat rounded quartz grains with an equal amount of feldspar (orthoclase, microcline and oligoclase). The minerals and their proportions are those of a granite, and yet the appearance of the grains and their relations to one another at once disclose the clastic character of the rock. The feldspar, except a few of the largest grains, is quite changed to kaolin or sericite, although its external characters are still plainly discernible.'

Indian lake is only an irregular expansion of the river crossing its downward course at a considerable angle, and discharging from the southwest side nearly a mile from the foot of the lake. Near Indian lake the banks are somewhat higher and are composed of greyish stratified clay, which makes a good soil. The shores of Indian lake are as a rule low and grassy, presenting no rock exposures, but the comparatively high hills that border the southwestern end of the lake are probably composed of quartzite-grit. From Indian lake to Round or Mountain lake the river flows with a very gentle current between banks of moderate height composed of stratified grey clay. As the first rapid is approached these banks are appreciably higher, but above the second rapid the area on either side of the river becomes much lower, while the immediate outlet from Round lake is flat and swampy. Both of the rapids below Round lake are caused by boulder obstruction. The southwestern shore of Round lake shows high hills composed of the coarse diabase or gabbro, and exposures of this rock were noticed on the northeastern side near the outlet, but to the northeastward of the lake the whole region seems to be comparatively level, the soil being a clay loam. The diabase and gabbro contain much flesh-red feldspar, greatly resembling in this respect the coarser portions of the rock exposed at Quinn point on Lake Timiskaming as well as on the northeast shore of Bay lake. When subjected to the weather this feldspar kaolinizes, thus producing a moderately coarse-grained rock, closely resembling in macroscopic appearance a basic hornblendic granite.

THE MATABITCHOUAN RIVER.

The Matabitchouan and Montreal rivers reach Lake Timiskaming almost at the same point; but while the general course of the latter is from the northwest, that of the Matabitchouan is from the southwest. The proximity of the mouths of these two streams has, in the past, been the cause of some little confusion in the names applied to each. Matabitchouan seems to have been the original Indian name of the Montreal river, while what has of late years been called the Matabitchouan is known to the Indians as the Wabos-na-ma-ta-bi-sipi (or Rabbit-sitting-down river). The names have now, however, become fixed as here employed. The Matabitchouan is one of the most important streams in this district, and for many years was the only canoe-route in common use between Lakes Timiskaming and Timagami. Its headwaters lie to the north and west of White-bear lake. The smallest branch takes its rise in Caribou lake, on the main canoe-route, within a quarter of a mile of the northeast arm of Lake Timagami, and this small lake sends another and larger stream into Lake Timagami. The largest or main branch of the river rises in Mountain lake, to the southeast of Annima-Nipissing and Bay lakes. Two other branches of some size drain lakes that lie close to the hills bordering the lower stretch of the Montreal river, debouching in the northeastern corner of White-bear lake within a short distance of one another.

From the mouth on Lake Timiskaming to Mountain lake, the distance, in a straight line bearing N. 70° W., is nineteen miles, while following the general canoe-channel this distance is increased to thirty-seven miles. This whole space is divided into two main directions of flow, forming an angle of 70° with one another, these constituting two sides of a triangle, while the third has the length and direction already mentioned. The first of these stretches, which extends from the south of the river to Rabbit lake, has an upward bearing of S. 44° W. for thirteen and a half miles, although the channel usually travelled measures about sixteen miles. The third side of the triangle, which reaches from Rabbit point to Mountain lake, shows a general direction of N. 26° W., with a length of nineteen miles, although the most direct canoe-channel measures about twenty-one miles. From the mouth of the Matabitchouan to the first portage the river has cut a fairly deep channel through drift material, the bands on either side being composed of a stratified grey clay. The strength of the current in this interval varies with the height of the water, for during times of freshet the water of the lake backs up, forming a comparatively deep channel to within a short distance of the first portage; while, during ordinary stages, the stream has a swift current almost to the mouth. The northern banks are as a rule much lower than those on the south side of the stream. A short distance south of the river is a high and prominent hill, known as the King of the Beavers, also sometimes called the Montreal mountain or Beaver mountain. According to barometrical observations this hill has an elevation of 660 feet above Lake Timiskaming, or 1,248 feet above the sea.

The summit of Beaver mountain, for 340 feet, is composed of a greenish-grey medium textured diabase, much sheared and broken, the planes of shearing abundantly coated with greenish decomposition products. Below this rock is a greenish slate, which marks the lower and more gradually sloping portion of the mountain. The strike of the slates curves around, conforming beautifully with the line of outcrop of the diabase, dipping into or beneath what seems to be an irruptive mass of laccolithic origin.

The first, or Matabitchouan portage, occurs a little over two miles from the mouth of the river, where a series of rapids and falls occur with a descent of 260 feet. The stream here describes a sharp bend to the north, while the portage to overcome these obstructions cuts across the bend thus formed, running over a hill, the highest point on the trail being 330 feet above the level of the river at the foot of the portage. The ascent of the portage is steep, passing first over stratified grey clay, and clay and boulders, but near the summit it is rocky. This is the breccia-conglomerate, containing pebbles chiefly of a flesh-red granite embedded in a dark-green chloritic matrix. The west end of the Matabitchouan portage comes out on the first of a series of four Bass lakes, numbered in ascending order. These are small expansions, united by narrow shallow channels, with an appreciable current.

The southeast shore of the Second Bass lake consists of high perpendicular cliffs composed of a fine-grained hornblende-granite, evidently an extension of the large mass of somewhat similar rocks coloured as Laurentian farther to the south. At the base of the cliff, near the upper end of the lake, this granite may be seen in contact with the breccia-conglomerate that constitutes the basal member of the Huronian. Precisely similar rock forms the eastern shore of the Third Bass lake, but is so massive that no lines indicating original sedimentation could be discerned. A thin section of the finer portion, or matrix, of this conglomerate, obtained from an exposure immediately below the rapid that separates this lake from the next succeeding one above, shows the rock to be a highly feldspathic sandstone or greywacké, consisting of subangular grains of quartz, orthoclase and plagioclase with a considerable amount of a green chloritic decomposition product occurring for the most part between the quartz and feldspar grains and giving the rock its general greenish tint. A few grains of pyrite are also present. The majority of the grains are composed of feldspar, which is a good deal decomposed, while the quartz shows evidence of having been subjected to great pressure. On the western shore of the lake, near the upper or south end, exposures of greenish banded slates may be observed, dipping to the westward at a low angle and overlying the breccia-conglomerate of the eastern shore. These slates constitute a belt about a quarter of a mile in width, and to the west merge gradually upward through a massive and uniformly fine-grained greywacké into the sea-green sandstone or quartzite-grit that forms most of the shores of Trout lake, (a small expanse of water to the northwest of Third and Fourth Bass lakes).

A rapid with a considerable fall intervenes between the two upper Bass lakes. Macdonald creek, an important tributary, enters the Fourth Bass lake from the south, draining a number of lakes in that direction. On the west shore of the bay into which this creek empties are high rounded exposures of the breccia-conglomerate, while at the small rapids at the upper or southwest end of the lake are ledges of the overlying greenish banded slates, striking about northeast and dipping to the northwest.

Above the Fourth Bass lake a small rapid occurs, and a short distance beyond five rapids follow in quick succession. During times of low water a portage known as the Kanebeatika (or Along-the-rocks) portage is made on the south side of the river, commencing at the foot of a small fall and running for a distance of nearly three-quarters of a mile. Frequently, however, the passage either up or down is made by keeping close to the stream and utilizing the shorter trails. The north side of the river shows precipitous cliffs of greenish banded slates, which rise abruptly from the water's edge to a height of over a hundred feet, having at the base a talus of angular blocks. Only a quarter of a mile separates these from the Devils rapid, where the water pours through a narrow cañon of slate, with a portage on the south side of the stream. The banded slates here exposed have a strike of N. 20° E., with a dip to the northwest. A quiet stretch of similar length separates this from the next succeeding rapid, at the foot of which the green banded slates strike N. 64° E. and dip northerly $< 50°$. The upper end of this portage shows exposures of a somewhat coarse gabbro or diabase, a belt of this rock about three-eighths of a mile wide crossing the river at this point and interrupting the slates and greywackés. A stretch of three-quarters of a mile of comparatively deep and navigable water, with swift current at only one point, occurs in the interval before the foot of the next portage, which is the last before Rabbit lake is reached. This portage, which is a little over a half mile in length, passes two rapids and a chute, the latter exhibiting a very pretty fall of about fifteen feet at the immediate outlet of the lake. A specimen obtained at the foot of the portage is a very fine-grained reddish-grey rock, resembling a felsite macroscopically.

At the outlet the rock is a fine-grained greenish-grey felsite or feldspathic sandstone very similar to the last in composition with a strike N. 60° E. and a dip to the northwest$< 50°$. It is impossible, however, to be sure that these planes represent original lines of sedimentation, for a little over a mile to the south of Rabbit chute, on the west side of Outlet bay, the greenish banded slates were seen dipping about west$< 50°$ and superimposed upon the breccia-conglomerate which forms the eastern shore of this bay wherever the rock is seen.

The present name, Rabbit lake, by which this stretch of water at the head of Rabbit chute is known, is an abbreviated translation of the Indian designation Wabos-na-ma-ta-bi (or Rabbit-sitting-down lake) because of the occurrence at one of the most prominent points of a large angular mass of greywacké which has a fancied resemblance to a rabbit in a sitting posture.

The lake has a general trend of northwest and southeast, and the distance from Rabbit chute to the end of Southwest bay is ten miles in a direct line, although the distance from portage to portage on the canoe-route is a little over eleven miles. The average width of the lake is about three-eighths of a mile, while its total area is about eight square miles, and its height about 939 feet above sea-level. The lake has a rather irregular outline, with a number of large bays, which are, in their turn, cut up into many smaller inlets. At the southern end of Outlet bay one of these indentations stretches away to the southeast, crossing the strike of the rocks for a distance of over two miles. During extreme high-water a small stream flows out of the end of this bay into Ross lake, at the headwaters of Macdonald creek, which flows into the Matabitchouan river at the Fourth Bass lake. The bay running to the northwest forms a portion of the main route of travel between Timiskaming and Timigami lakes. With a gradual curve from the north to the northwest it reaches the foot of the portage to White-bear lake, about five miles from Rabbit point. The Southwest bay is really a continuation in this direction of the main body of the lake.

Near the southern end of Outlet bay a mass of greenstone (diabase and gabbro) crosses Southeast bay, and, running parallel to Outlet bay, but a short distance inland, this doubtless connects with the belt of such rocks that crosses the Matabitchouan at the third rapid below Rabbit chute. This band is a little over half a mile in width, and in the vicinity of Outlet bay is followed by the massive breccia-conglomerate, which is in turn overlain by the fine-grained brownish, and greenish-grey slaty rocks with a strike of N. 5° W. and a dip west < 20°. This diabase, as it may be named, is by no means homogeneous in composition, and patches of granitic aspect and composition occur without any sharp line of division, merging by degrees into the more basic portion of the mass. In places these granitic patches are cut by dikes of fine-grained diabase evidently of somewhat later origin.

To the south of this greenstone mass a belt of the breccia-conglomerate comes in, but the actual contact is hidden in a low valley at the foot of a small bay on the southwest shore. On the southwest side of the bay the conglomerate band has a width of a quarter of a mile, but on the northeastern shore it is somewhat wider. The matrix is a fine-grained, compact, dark greenish-grey rock, breaking with a conchoidal fracture. Under the microscope it is seen to consist of a very fine-grained mosaic of quartz and feldspar, filled in with minute scales of chlorite and sericite and granules of epidote. In this are scattered larger fragments of quartz, orthoclase, plagioclase, microcline, hornblende, biotite (both the latter minerals largely altered to chlorite) and sphene. In this fine-grained portion are embedded occasional pebbles and fragments often of considerable size, composed chiefly of red and grey granite. Near the contact with the granite rocks to the south the rock is seen to have undergone extensive deformation by pressure, the resulting shearing-planes being abundantly coated with the usual greenish products of decomposition. The pebbles themselves, which are relatively much more abundant, are seen to have been stretched and rolled out as a result of such extreme dynamic action; while a very marked foliation has been developed in the finer-grained portion of the rock, which is seen to wrap around and conform as closely as possible to the outline of each individual fragment.

Besides these lengthened pebbles there are granitic inclusions, running for the most part with the cleavage, but which in most cases present a somewhat more irregular and indistinct outline. These appear to be of the nature of small apophyses of granite, although it is exceedingly difficult to discriminate in every case between these irruptive dike-like intrustions and the distinctly rolled fragments which have been considerably flattened as a result of pressure. The cleavage or foliation of this conglomerate has a direction varying from S. 18° W. to S. 21° W., with a prevailing southeasterly dip at a high angle.

The junction between this rock and the granites and gneisses exposed to the south was seen crossing the lake about three-quarters of a mile from the foot of Southeast bay. The line of outcrop of the granitite-gneiss seems to form a considerable angle with the planes of foliation of the conglomerate, intersecting these in a direction of S. 53° W. Farther to the south the granitite-gneiss is considerably mixed with a much more basic rock, doubtless either a gabbro or a gabbro-diorite, which, however, appears to have been an integral portion of the same magma from which the granitite-gneiss has solidified. The gneiss is, as a rule, very granitoid in aspect, sometimes very coarse-grained and even porphyritic in structure, while in other places not far distant it is of medium texture and distinctly foliated, this structure being determined by the alternation of reddish and greenish-yellow bands. The strike of this foliation varies from N. 23° E. to N. 33° E., while the dip is to the northwest $<45°$ to 50°. Under the microscope a precisely similar rock from the Southwest bay is seen to be a granitite-gneiss, composed of orthoclase, plagioclase, quartz, chlorite(derived from biotite originally present) and epidote, with small quantities of sphene, apatite, and secondary calcite. The alternation of reddish and greenish-yellow bands so characteristic of this rock is due to the parallel disposition of certain layers of feldspar stained by iron oxide, with others in which the feldspars present have undergone extensive saussuritization; the resulting scales and granules of sericite and epidote arranging themselves in a more or less definite position at right angles to the direction of pressure. This granitite-gneiss and associated granitite, with a much smaller proportion of 'greenstone,' occupy all of the southern end of Southeast bay, and are continuous with the large mass of essentially similar Laurention rocks exposed in the region to the south.

The contact between the granitite-gneiss and the slate-conglomerate is very evidently of an irruptive character. The slate-conglomerate is everywhere, near the line of contact, much squeezed, and is in places penetrated by small dikes of the irruptive rocks ; while fragments of the former may be seen caught up and embedded in the gneissic-granite, even at a considerable distance from the line of junction, on both sides of the bay. Near the line, the matrix of the conglomerate is much hardened as a result of such igneous action, or rendered much more chloritic and epidotic as a result of the presence and percolation of heated waters. On the northeast shore, near the contact between the two rocks, the foliation of the granitite-gneiss dips to the northwest< 30°, while the conglomerate has an almost if not quite vertical attitude; although farther to the north it dips to the northwest< 50°.

The southern shore of the main body of Rabbit lake is composed of a very distinctly and evenly bedded slaty graywacké, of grey and greenish-grey colours, the greenish colours being due to the relatively greater abundance of sericite and chlorite. The strike varies from N. 18° E., on the shore opposite Rabbit point, to N. 40° E. near the northeastern part of the stretch, curving gently with the trend of the shore. The banks rise rather abruptly from the water's edge, in places forming low vertical cliffs of slate, especially near the northeastern portion. The effects of glaciation are very marked. The graywacké-slate rests conformably upon the breccia-conglomerate which forms the northeastern shore of this portion of the lake wherever any outcrops of rock occur, the bank shelving gently, as a rule, towards the lake with a gravel or shingle beach along the water's margin.

To the southwest the breccia-conglomerate extends to Rabbit point, as well as along the east shore of Northwest bay for some distance north of Rabbit point. The various exposures of this conglomerate show no special features worthy of mention in this place.

Rabbit point is a narrow projection that extends into the lake from the north side of the junction between the main lake and Northwest bay, a little over six miles from Rabbit chute. The rock composing it is the prevailing breccia-conglomerate, but, as in most cases, it is exceedingly difficult if not impossible to determine any lines of stratification, and the cleavage or foliation, which is the most obvious and only distinct structural feature present, has a strike of N. 15° E., and a dip S. 75° E.< 80°.

There are two small islands about the centre of the lake a short distance to the west and northwest of Rabbit point. The larger and more northerly of these is composed of dark greenish-grey breccia-conglomerate, the matrix of which has a distinct slaty cleavage. The pebbles and boulders are composed chiefly of red and grey granite, and sometimes of reddish-grey gneiss. The inclusions vary in size from the smallest pebbles to boulders two feet and over in diameter. Besides these composite fragments there are a great many angular pieces of feldspar, which, where they are abundant, give the rock a pseudo-porphyritic appearance. Most of the fragments are composed of a deep flesh-red granite, showing a preponderance of red feldspar with a less quantity of grey translucent quartz, and a trifling amount of green chlorite resulting from the decomposition of biotite. Next in abundance is a reddish-grey granite somewhat more basic in composition than the last, while in certain instances occasional rounded fragments of a distinctly foliated reddish-grey gneiss were noticed. Besides these there are fragments that seem to be referrable to some of the finer and more compact slaty greywackés of the Huronian.

In addition to this distinctly clastic material some granite inclusions were seen with an irregular though lenticular outline, pegmatitic in structure and origin. Such patches or areas were sometimes six and even eight feet in length, which coincides with the direction of the foliation of the enclosing rock. The strike of the foliation, which is distinct, is N. 6° E., with an almost vertical attitude. The smallest of these islands is composed of a very similar rock, but more massive in structure. Around the included masses, especially the larger ones of granite, the rock has an apparent flow-structure, with lines conforming as closely as possible with the outline of the included fragments. The whole rock-mass has very evidently been subjected to intense pressure, which has completely destroyed any bedded structure which may have originally existed and replaced it by a more or less perfect jointed structure.

Opposite these islands, and forming the eastern shore of the lake, is the same greenish-grey breccia-conglomerate, with a foliation striking N. 8° E., and a dip to the east varying from 60° to nearly vertical. To the south, as the mass of diabase or gabbro is approached, the breccia becomes much more contorted and broken up. The included fragments are flattened and rendered irregular in outline, and the whole mass exhibits abundant signs of pressure and alteration.

At the immediate contact the conglomeration does not contain many fragments, and the finer slaty matrix is sometimes alone represented; but a short distance away the fragments are so abundant that there is very little of the finer interstitial material. The junction between the two rocks is situated a little over a mile and a half south of Rabbit point. It is very sharply defined and the slaty rock along the line of demarcation is much broken up and jointed, although the cleavage planes conform in a rude way with the line of outcrop of the greenstone. The slate is likewise much hardened, as a result of the intrusion, and breaks with a splintery fracture. The greenstone, which is essentially similar to most of these basic masses, is doubtless a diabase, possessing a dark greenish-grey colour and of medium texture. In places it has a decided reddish tinge, owing to the feldspar being stained with hydrous oxide of iron. This greenstone contains a considerable body of chloritic and epidotic schist, which may have resulted from the shearing of a portion of the eruptive itself, or may represent an extremely altered form of the finer matter of the breccia-conglomerate caught up and embedded in it.

Towards the end of the outcrop, which altogether occupies scarcely a quarter of a mile of shore-line, the rock is of a prevailing grey colour, and much coarser and gabbro-like in structure. Southwards it gives place, at the end of a small bay, to a greenish-grey feldspathic quartzite associated with some very vitreous flesh-red quartzite. In general, near the contact, these rocks have a north and south trend, but about an eighth of a mile to the southeast the greenish-grey greywacké was seen apparently striking N. 23° W. and dipping northeasterly $<$ 60°, but it is improbable that the planes represent true bedding.

The mass of greenstone described above seems to be closely connected genetically with the large mass of granite and similar basic rock, portions of the former occasionally being exposed along the southern and western shores of Reuben lake to the west. By far the greater portion, however, of the shores of Reuben lake, show outcrops of the breccia-conglomerate, full of granitic and other inclusions and fragments, and much hardened and altered. It seems probable that not only is the large mass of granitic and other eruptive rock in close proximity to the west, but also that at no very great depth beneath similar rocks prevail. The southern and eastern shores of the southwestern extremity of Southwest bay are composed of the breccia-conglomerate with a decided slaty or schistose structure. On the south shore the direction of foliation varies from S. 28° W. to S. 38° W. and the dip southeast $<$ 65° to 70°. The rock, although of a prevailing light greenish-grey colour, frequently presents pearly-green cleavage-planes, due to the development of sericite. In this schistose matrix are embedded pebbles and fragments composed chiefly of the red granite.

Two streams enter the small bay forming the southwestern end of Southwest bay. Both of these small streams come from the west, the more northerly, forming the outlet of Reuben lake, flows down steeply over angular and detached blocks of slate. The other larger and more important stream comes in about an eighth of a mile from the foot and drains many small lakes situated to the west and northwest.

The northwestern and western shores of this small bay are occupied by the greenish-grey slaty greywacké and breccia-conglomerate, and at one place near the stream from Reuben lake massive and jointed slaty feldspathic sandstone forms high perpendicular cliffs. These rocks extend for a little over a quarter of a mile along the shore from the mouth of this stream, where they are interrupted by an irruptive mass composed of a greenish-yellow and flesh-red granite-gneiss in alternating layers. Near the contact the granitic inclusions in the breccia-conglomerate become more irregular in outline, and many of them evidently represent dike-like apophyses of an originally plastic mass which have been injected through the various cracks and fissures in the slaty rock.

This gneiss is of medium texture, and the foliation, which is very distinct, is caused by the parallel arrangement of flesh-red and greenish-yellow bands in alternating sequence. The microscope shows the rock to be composed chiefly of orthoclase, plagioclase, quartz, chlorite, (representing the biotite originally present) and epidote with smaller quantities of sphene, apatite and secondary calcite. In this gneiss the reddish bands owe their colour to the predominance of feldspar stained by iron-oxide, while the yellowish-green portions represent bands in which the feldspar has undergone extensive saussuritization. The strike of the foliation is S. 58° W. and the dip N. 32° W. < 70.

The gneiss occupies the shore southward as far as the stream which comes from the west, a distance of a little over an eighth of a mile. It evidently represents an extension of the much larger mass of similar rocks exposed in the region to the south and southwest. A mass of the slate-conglomerate was seen included in this gneissic rock with granitic intrusions of irregular outline traversing it in various directions. This mass does not extend farther, for the eastern shore shows continuous exposures of a very fissile and altered greywacké-slate. This slaty rock was noticed in several places to contain fragments of granite and feldspar, while at other places they are rare. The rock has evidently been subjected to somewhat extensive alteration and deformation, the exposed edges showing the characteristic wrinkled surface of slaty rocks which have been exposed to great pressure. The strike of the foliation varies from N. 20° E. near the foot of the bay to N. 30° E., near the northeast end. The western shore, south of the mouth of the small stream near the end of the bay, is likewise composed of similar slaty rocks, which vary in strike from N. 3° E. to N. 13° E. These evidently belong to a wedge-like strip, which, inland, quickly ends, and to the southwest is represented only by a number of detached masses caught up and embedded in the granitoid gneiss exposed on the southeastern shores of Rankin and Miller lakes.

The western shore of the Northwest bay of Rabbit lake is composed of the prevailing breccia-conglomerate, but generally so massive that no distinct stratification can be made out, although usually the rock seems to strike with the trend of the shore and dip towards the lake. At one place it forms a cliff named Echo Bluff, over a hundred and fifty feet in height. A little over a mile and a half north of Rabbit point this slaty rock is replaced by a greenish-grey diabase which occupies the shore as far as the first narrows, nearly two miles farther to the northwest. Towards each side of the mass the texture of the diabase is rather fine-grained, but near the centre it is much coarser and granitoid in structure, and as a great deal of the feldspar assumes a flesh-red tint the rock bears a marked macroscopical resemblance to a basic hornblendic granite. In general, however, the rock is medium-grained and diabasic in structure and composition. This basic eruptive extends across the lake to the northeast shore, where it forms a small patch, the strike of the neighbouring slaty rocks curving around its line of outcrop. A large patch of the greenish-banded slates was noticed caught up in this mass of greenstone, still preserving its bedded structure, with a dip of N. 65° W.< 45°. North of Rabbit point, on the east shore of Northwest bay, the breccia-conglomerate merges gradually upward into a fine-grained greenish-grey feldspathic sandstone, interlaminated with much finer-grained and darker coloured, banded greenish slates, the cleavage striking N. 4° E., with easterly dip< 80°. The dip of the bedding seems to be to the northeast at a comparatively low angle. This compact greenish grey fine-grained greywacké was examined under the microscope, and found to consist chiefly of irregular and subangular fragments of quartz, orthoclase and plagioclase embedded in a matrix composed chiefly of chlorite and sericite, which give the prevailing greenish tint to the rock. The other minerals noticed were zircon, sphene, ilmenite accompanied by leucoxene, tourmaline and large grains of apatite and epidote. These minerals have evidently suffered but little abrasion through the action of water.

To the north of the small area of greenstone exposed on the northeast side of this bay the shore is occupied by greenish slates, banded by the alternation of dark-green and purplish layers which merge into one another. These slates have a strike of S. 42° E., and a dip to the northeast < 40°. The thin section shows the character and composition of these bands very clearly. Some of the lighter ones exhibit an augen structure, the lenticules being composed of small angular fragments of quartz, with a lesser proportion of feldspar. Surrounding and curving around them are the darker-coloured bands which derive their colour from the relatively greater abundance of small opaque fragments of magnetite. The rock in general may be said to be composed of a fine-grained groundmass of feldspar, which is now greatly decomposed into sericite, occurring in the form of minute light-yellow-green scales, chlorite and granules of epidote. Irregular areas composed of aggregates of chlorite scales, together with small grains of magnetite, are scattered throughout the section.

At the first narrows, about three miles and a half north of Rabbit point, beautifully banded slates of a prevailing pale greenish-grey colour occur. The colour striping is produced by the occurrence of darker and almost black folia lines, which doubtless represent a relatively greater abundance, in these portions of the rock, of grains and dust-like particles of magnetite; while the lighter-coloured bands, originally highly feldspathic, contain a considerable quantity of yellowish-green sericite in minute scales and flakes, developed at the expense of the feldspar, together with a little chlorite derived from the alternation of the bisilicate material originally present in the rock. The outcrop is not far removed from the greenstone mass exposed on the opposite or southwest shore, and seems to have undergone considerable disturbance as well as alteration at the time of the intrusion of the greenstone, the slate dipping to the northwest < 30°.

Beyond this the lake narrows and for about three-quarters of a mile has the character of a stream, including a small rapid. A little above it widens out again into a small lake-like basin, the southwestern shores of which are composed of the massive greenstone.

The portage into White-bear lake begins at the northwestern end of this small lake, which is usually considered as a part of Rabbit lake, although not on the same level. The path is scarcely half a mile in length, and runs on the north side of the stream, which here trends nearly east and west.

White-bear lake was so called for a former chief of the Timagami band of Indians. As will be seen by a reference to the map it has a very irregular outline, and only a little over three miles of the southwestern part is traversed on the canoe-route to Timagami lake, the greatest portion of the lake lying to the northeast. The principal bays, making up the larger portion of the whole surface, have a trend a little east of north, thus coinciding with the strike of the clastic rocks exposed on the shores.

These are connected by shorter intervening stretches, excavated almost at right angles to the strike of the rocks. The width of a quarter of a mile or a little over is remarkably uniform. The prevailing clastic rock in the southern and western part of the lake is the breccia-conglomerate. The rock is, as a rule, massive and jointed, and the cleavage, which is the only structure visible, has a strike of about north and south with a dip to the east$<60°$, according in a general way with the line of outcrop of the greenstone. The greenstone, or diabase as it seems to be, occupies the whole of the western shore of the southern bay, as well as the large island near the eastern shore about the central part of the lake. It also forms the extremity of White-bear point and the high promontory on the south shore separating the eastern from the western portion of the lake. A small mass was likewise noticed on the northwest shore of the lake about a mile southeast of the inlet from Friday and Obashkong lakes.

On the long portage between White-bear and Bogie lake the rock wherever exposed to the usual breccia-conglomerate shows a preponderance of granitic fragments enclosed in a dark greenish-grey chloritic matrix. In the northeastern part of the lake the lowest clastic rock overlying this breccia-conglomerate is a dark greenish-grey fine-grained greywacké, having in places a somewhat slaty cleavage corresponding with the bedding. The dip is in general about S. 75° E.$< 25°$. This passes gradually upward, through an interlaminated lighter coloured feldspathic sandstone, into a yellowish-green or greenish-grey quartzose sandstone or grit, much coarser in texture and more massive in structure than the greywacké.

A short portage intervenes between the shallow muddy bay forming the western extremity of White-bear lake, on the road to Timagami, and another shallow arm of Crooked lake or Kinabigo-sminise (Snake Island lake.) The lake has its greatest length from northwest to southwest of nearly two miles. The rock, wherever exposed, is the massive breccia-conglomerate, in many places containing numerous pebbles and fragments, chiefly of red granite, embedded in a dark-greyish compact feldspathic matrix. The strike of the most distinct structural planes, doubtless those caused by pressure, is S. 47° E. with a dip to the northeast$< 65°$. A portage of less than a quarter of a miles separates Crooked lake from Caribou lake, the trail passing over a considerable rise composed of the breccia-conglomerate, while another portage of nearly the same length intervenes between Caribou lake and the small bay which marks the northeastern extremity of the northeast arm of Lake Timagami. Caribou lake, or Sagibanwanapikunk is scarcely three-quarters of a mile long and the rock seen is the massive breccia-conglomerate, the same rock continuing over the portage to Lake Timagami. This lake has two outlets, the ordinary and larger one flowing out of the west end into a small bay to the southeast of the one entered by the portage, while during times of high water another small stream flows out of the eastern end into Crooked lake.

Three important tributaries or branches of the Matabitchouan river enter the northern part of White-bear lake. The main branch reaches the northwestern corner of the main body of the lake about half a mile north of White-bear point. This stream takes its rise in Mountain lake, while many important tributaries enter from the west, draining the larger portion of the rocky granite plateau situated between it and the lakes draining towards Lake Timagami. Another stream flows into the small bay marking the northeastern extremity of White-bear lake, affording an outlet to a chain of waters which extends to within a distance of two miles southwest of the Montreal river. The third branch empties into the same bay about three-quarters of a mile to the southwest of the mouth of the last, draining several lakes, the largest of which is known as Waibikaiginaising or Reb lake.

Ascending the main branch of the Matabitchouan a portage of nearly half a mile separates Net lake from White-bear lake into which it flows, the trail being to the northeast of the connecting stream. The lake has a general trend of N. 36° W. and the distance from portage to portage in a straight line is nearly seven miles. The narrows from which the lake takes its name are situated a little over three miles from the White-bear portage. This contraction is a little over half a mile in length with an average width of about two hundred feet. South of the narrows a bay extends from this part to the northeast for about two miles, at the end affording an entrance to a stream that drains a series of lakes to the east and northeast.

To the northwest of the narrows a bay extends to the southwest for about a mile and a half. A comparatively large sheet of water, known to the Indians as Kanichee-kinikisink lake, lies to the northwest of this bay, into which it empties by two outlets, situated about a mile from one another. The northern portion of the lake, towards the inlet, is comparatively narrow, never, as a rule, exceeding a quarter of a mile in breadth, and frequently contracted to a quarter of this distance. The outlet from Thieving-bear lake discharges at a point a few chains from the northern extremity of the lake, while the stream, from Snare and Mannajigainia lakes, enters this lake nearly a mile to the southwest of this point.

The rock exposed in the southeastern end of Net lake is a massive compact dark greenish feldspathic sandstone, associated with small areas or masses of intrusive greenstone. This is succeeded to the northwest by a flesh-red granitite of somewhat coarse texture, composed of reddish feldspar, greyish translucent quartz, and a sparing quantity of greenish bisilicate material, which was originally biotite and is now almost completely altered to chlorite. This rock occupies the whole of the northeastern shore in the wide space to the south of the narrows. It also composes the southwestern shore and the islands with the exception of about half a mile in the vicinity of the narrows, where there are outcrops of a coarse dark greenish-grey greenstone. The shore-line characterized by the presence of these rocks is fairly bold, in somewhat marked contrast to those where slaty rocks prevail. There are no outcrops of rocks in the narrows. To the northwest of the narrows, however, the shores, as well as the bay which runs to the southwest, show many outcrops of a light greenish-grey slaty rock, evidently originally a compact greywacké, with an abundant development of sericite along the planes of cleavage. These slates or sericite-schists have a strike in accordance with the general trend of the bay, which is northeast and southwest.

The southwestern shores of Kanichee-kinikisink are generally composed of a somewhat similar though more compact slaty greywacké, but the northeastern side and many of the islands exhibit greenstone, which seems to be a different portion of the same magma, which to the north and northeast has, for the most part, solidified as a biotite-granite or granitite. The shores of the northern portion of Net lake are composed of a series of rounded rocky points with intervening marshy or grassy bays, the rock everywhere exposed being a flesh-red granitite in which but little of the ferro-magnesian constituent can be seen. Occasional small patches of greenstone were also noticed that appeared to be closely related to the granitite.

A short stream separates Net lake from Thieving-bear lake, with a small rapid near the latter and a much larger one near the former. Thieving-bear lake, or Mako-gimodiwi, has a very irregular outline, being completely enclosed by comparatively low rounded hills of the flesh-red granitite. It has three feeders from the north. The route from Thieving-bear lake northward to Mountain lake follows a succession of five small lakes or ponds, the largest of which is only a little over a quarter of a mile in length, united by small streams. The whole distance is about three miles by the stream and the general direction nearly north. The valley is as a rule somewhat narrow and shallow, the hills on either side sometimes rising abruptly from the water. The rock throughout is the prevailing flesh-red granitite.

Mountain lake has a general trend of a little north of east, and is about three miles in length in this direction. The western half of the lake, out of which the portage goes to Breeches lake, is a long narrow and shallow bay, and the rocks wherever visible are flesh-red granitite. The main body of the lake is nearly three-quarters of a mile wide, while the enclosing rocky shores are everywhere composed of the massive greenstone. The portage from Mountain lake, which here marks the height-of-land between the Matabichouan and Timagami waters, passes over the side of a hill, the highest point on the trail being 160 feet above Mountain lake. Breeches lake, or Kawaganchigania, is small. It empties into a pond which in turn discharges into a bay of Annima-Nipissing lake. A portage of only three chains separates Breeches lake from the small pond, while another scarcely an eighth of a mile brings the traveller to the large and important sheet of water known as Annima-Nipissing lake.

Ascending the stream flowing into the northwestern bay of Net lake, about four and a quarter miles from the White-bear portage, the channel of the creek is utilized for a little over a quarter of a mile, when a very short carry is necessary to reach Ferguson lake. Duncan lake, the next expansion encountered, is practically on the same level, being separated by about a quarter of a mile of stream with little current. The shores of both Duncan and Ferguson lakes slope gently and show no rock. The second portage going from the west end of Duncan lake at the stream from Petrout lake is about forty-five chains in length, and runs over hills which are composed chiefly of the flesh-red granitite. Within a short distance of the east end of the portage this rock is succeeded by breccia-conglomerate of the usual character, which outcrops on the west short of Petrout lake a short distance north of this portage. On the opposite side of the lake a coarse greenish-grey quartzite-grit may be seen resting directly upon the dark greenish-grey slaty rock. The junction is close to the edge of the water and is sharp, without any of the customary transition from one rock to the other. Both rocks dip to the east at a comparatively low angle. The southern end of Petrout lake is a shallow muddy bay, and the portage into Lily lake is along the boulders in the stream. The rock on the west side of Lily lake is the breccia-conglomerate, showing the usual fragments of red granite, while on the east side the slates, which are above, are themselves overlain by the quartzite-grit that rises into rather high hills a short distance east of the lake.

A portage of seven chains separates Peeshabo lake from Lily lake into which it empties. The rock on the northern and southwestern shores of the lake is the breccia-conglomerate presenting no unusual features. A mass of flesh-red granite ,evidently co-extensive with the one exposed on the southeastern portion of Net lake, comes out on the west shore of the lake, occupying a little over half a mile of shoreline and an off-lying island. On Bogie lake, to the south of Peeshabo lake, the prevailing rock is again breccia-conglomerate. A portage of three chains separates it from Peeshabo lake. A trail nearly a mile and a half long runs from the southwestern end of Bogie lake to a hunting camp on the north shore of White-bear lake, about half a mile northeast of the inlet from Net lake. The rocky ridges over which it runs are all composed of the greenish-grey breccia-conglomerate.

To the north of Petrout lake a portage thirteen chains in length leads into Granite lake, about a mile and a half in length, although it is only about three-quarters of a mile from the portage at the outlet to that at the mouth of the inlet on the east side, about half way up the lake. A short carry of a little over a quarter of a mile of creek intervenes before James lake is reached. Granite lake, as the name implies, is completely surrounded by granite, with the exception of small masses of greenstone on the southern and southeastern shores. The shores of the southern part of James lake show exposures of greenstone, associated with patches and areas of a dark greenish-grey feldspathic sandstone through which it seems to be intrusive. The northern end of the lake is all composed of the flesh-red granitite.

The portage from James lake to Waibaikaignaising lake starts from a point on the east shore of the former, about half a mile north of the outlet. It is nearly thirty-five chains in length, and comes out on the west side of a small basin, forming the southwestern extremity of Waibikaiginaising lake. The outlet of this lake flows to the south from this basin-like expansion, ultimately reaching White-bear lake about three-quarters of a mile southeast of its northeastern extremity. Waibikaiginaising or Reb lake is a little over six miles in length, and has, in general, a trend of a little west of north. About half a mile from the northern end a boulder obstruction, doubtless of morainic origin, runs almost completely across the lake at right angles to its general direction, leaving only a very narrow channel near the western side. The western shore of the lake, wherever rock exposures were seen, is underlain by the breccia-conglomerate presenting the usual dark greenish-grey matrix with embedded fragments and pebbles of eruptive material. The eastern shores of the southern half of the lake show rather continuous exposures of the well banded greenish, compact greywacké-slates, upon which is superimposed the coarse yellowish-green quartzite-grit, both rocks dipping to the east< 25°. Both shores of the northern part of the lake are composed of the quartzite-grit as far as the inlet from Johnny lake.

The portage into Johnny lake is nearly eighteen chains long and runs to the northeast of the creek connecting the two lakes. Here a mass of greenish-grey diabase intersects the quartzite, rising into somewhat high and precipitous cliffs. This belt of diabase is about half a mile in width and is evidently an extension eastward of the huge mass exposed on the shores of Annima-Nipissing and Mountain lakes. The shores and islands of the northern part of Johnny lake are composed of the massive and compact breccia and conglomerate, much jointed and broken and filled with very numerous pebbles and fragments of various eruptive rocks.

The stream from Cliff lake empties into Waibikaiginaising lake at a small indentation of its eastern side, a little over two miles from the south end. The portage is about thirty chains in length and runs a short distance north of the stream. The canoe-route utilizes only the northern part of Cliff lake, coming in at the northwest corner and going out at the end of the small bay running to the northeast. The lake itself is about a mile and a quarter in length and has a general trend a little west of north. The yellowish-green quartzite-grit rises into high hills on either side of the lake, especially towards the east, where high precipices mark the western faces of hills that rise to an elevation of from 400 feet to 500 feet above the lake. These hills present less abrupt though still steep slopes on their eastern side to the west of Friday lake. The strike of these greenish quartzites runs from N. 25° W. in the southern part of the lake to nearly north at the northern extremity, while the dip is to the east< 20° to 25°. The portage from Cliff lake to Summit lake follows up a steep gully between high ridges of quartzite to the south and others of diabase to the north. The highest point on the trail is 190 feet above Cliff lake and is only six chains west of Summit lake, while the fall towards the latter is seventy feet. The lake itself is only a small pond about a quarter of a mile in length, the outlet flowing from the northeast comes into a beaver-meadow and thence eastwards to Friday lake. The northwest shore of Summit lake is composed of diabase, an extension in this direction of the band crossing the foot of Johnny lake, while the rest of the shore-line shows outcrops of the greenish quartzite. The next portage runs from the northeast end of Summit lake to a beaver marsh, along the eastern margin of which the path runs for some distance, when it turns eastward towards Friday lake.

Friday lake is completely enclosed by hills of coarse sea-green feldspathic sandstone or quartzite-grit. The lake has a general direction of a little west of north and is four miles in length, with an average width of a quarter of a mile. A trail a little over half a mile in length runs from a small bay on the east side of the lake, about a mile from the north end, to a small expanse of water that we called Wilson lake and which has the distinction of being the highest lake of which we have a record throughout the entire area of the present map-sheet, being about 1177 feet above the sea.

To the northwest of Friday lake a short portage runs to Prudhomme lake, the southern part of which is extremely shallow and is enclosed by the greenish quartzite, but the narrows beyond show outcrops of diabase which appear to belong to a belt over an eighth of a mile in width, forming a continuation in this direction of the mass exposed to the northwest of Summit lake. Northwestward it runs towards the large mass which characterizes the district on either side of the Montreal river in the vicinity of Horner chute, with which it seems to be continuous. The southwestern shores of the northern part of Prudhomme lake show outcrops of the greenish quartzite striking N. 25° W. and dipping S. 65° W. $< 36°$, while on the opposite side the underlying slates dip S. 70° W. $< 35°$.

Between Friday and White-bear lakes the distance in a straight line is about six miles and a half, and the valley occupied by the connecting stream and lakes shows a gradual bending around from a little east of south to southwest. The river shows alternating deep stretches, some of them through extensive beaver-meadows, connected by narrow rocky or boundary spaces which require to be portaged. Five portages at least have to be made before reaching the small lake crossed by Nivens meridian line, to avoid these rough pieces of stream. The stream is utilized for about three-quarters of a mile below this small lake where a portage over half a mile in length is made to avoid the rough and obstructed river. A trail a little over half a mile long runs from the foot of this portage to Bear lake to the east of this point. Below this portage the stream meanders with a comparatively deep though crooked channel for a distance of nearly a mile, when a short portage is made on the northeast side of the stream into Obashkong lake. This lake is about two miles in length.

Bear lake, which flows into the Matabitchouan river below Rabbit chute, has a general trend of nearly north-and-south, and is a little over six miles in length. It rarely measures a quarter of a mile in width. The shores are everywhere composed of greenish quartzite with some associated intrusive greenstone at the southern end. There are two outlets, both of which, however, unite in a small lake to the south. The stream is rarely travelled and the country on either side is exceedingly rough and uneven. Three small lake-like expansions intervene between Bear lake and the Matabitchouan, united by rough, rocky and usually rapid channels. The slate which underlies the quartzite is not met with until the immediate vicinity of the Matabitchouan river is reached.

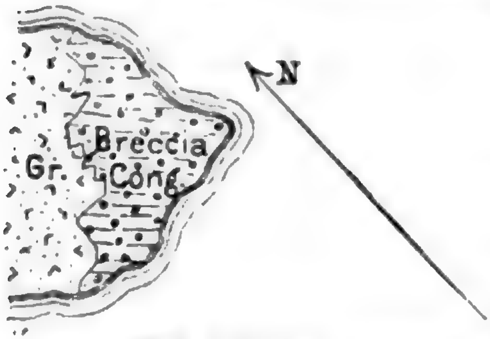
MACDONALD CREEK.

The rocks seen along this stream are particularly interesting and throw considerable light on the structural relations existing between the Laurentian and Huronian. The stream has never been much used as a canoe-route, and therefore need not be described at length. It consists of a series of lakes united by shallow rocky or bouldery channels, which necessitate frequent portages. From the outlet, at the northeast corner of the Fourth Bass lake on the Matabitchouan river, to Moxam lake it occupies a gently curving valley with a general southerly direction, but the extension of this depression southward meets rising land which forms a watershed in this direction. The upper portion of the stream from Moxam to Ross lake occupies a valley trending almost northwest. Ross lake, marking the headwaters, is only a couple of feet lower than Rabbit lake, a decided hollow connecting the two lakes, and during times of freshet a certain amount of the water of Rabbit lake escapes into Ross lake. The first three expansions at the head of this stream, viz: Ross, Burwash and Moxam lakes, differ little in level, and the short stream connecting them exhibits very little current. From Moxam lake, however, down to the mouth, the fall is seventy feet, most of which occurs between Cooper lake and the Matabitchouan, this distance of a little over half a mile showing a fall of fifty feet.

The shores of Ross lake are composed of a coarse red granitoid-gneiss, evidently by its composition a granitite. Some portions are more basic in composition and darker in colour where the biotite has segregated during its consolidation, and these patches or areas show a very distinct foliation. In some outcrops the rock is porphyritic and the phenocrysts of flesh-red feldspar are developed in a finer-grained feldspathic groundmass showing streaks of yellowish-green epidote. At one point on the west shore a mass of fine-grained greenstone was seen associated with the granite in such a way that both had apparently solidified from the same magma, differing only in their rate of cooling. The gneissic rock is certainly newer than the greenstone, irregular dike-like masses of the former penetrating and ramifying through the latter.

The point on the southeastern shore of this lake towards the outlet is occupied by the prevailing breccia-conglomerate holding pebbles chiefly of reddish and reddish-grey granite. These inclusions vary greatly in size, some being as much as three feet across. Occasional fragments are quite angular in outline, some are subangular, while the majority have been more or less perfectly rounded. The contact between this comparatively small area of clastic rock and the granitite-gneiss in which it is doubtless embedded was not seen, although only a short distance intervened between the exposures of the two rocks. The greater portion of the small island in the southern part of the lake is composed of coarse reddish granitite-gneiss. The island runs in a northeast direction and is about three chains in length. Its northeastern point is composed of the breccia-conglomerate, full of small pebbles as well as angular fragments, chiefly of red and grey granite. The contact between the two rocks is sharp and jagged and re-entering angles filled with the material of one rock penetrate the substance of the other.

FIG. 4.



Scale 40 ft. inch.
SKETCH SHOWING THE LINE OF JUNCTION AT NORTHEAST POINT OF SMALL ISLAND IN BASS LAKE.

The rock near the northwest end of Burwash lake is, as a rule, well foliated and of a deep flesh-red colour, the strike being N. 19° E. and the dip northwest at a high angle. Some of the gneiss is very massive and granitoid, in places porphyritic, the phenocrysts of feldspar being very sharply outlined in a dark-greenish chloritic matrix. This rock seems to be the prevailing flesh-red granitite-gneiss, the biotite originally present being decomposed to chlorite. Similar rock is present on the northwest shore of Moxam lake, striking N. 29° E. and dipping southeasterly $< 60°$.

On the southeast side of Moxam lake, in the southern part, and also in the bay running to the southeast, the gneiss is not only very distinctly foliated, but well laminated. It is the usual interlamination of the reddish and greyish granitite, presenting the common alternation of lighter and darker coloured bands. The strike is N. 48° E., and the dip southeast $< 53°$.

The gneissic rocks in the vicinity of the narrows in the northeastern part of the lake show a gradual curving around in strike from N. 4° W. at the southern end to N. 40° E. a little to the north of this contraction, while the angle of inclination varies from 45° to 60°. At one point on the northwest shore, nearly three-quarters of a mile from the outlet, the granitite-gneiss is of a deep flesh-red colour weathering on exposure to a brick-red. It is massive, distinctly foliated, but much affected by jointing, so that it is exceedingly difficult to obtain a hand specimen. Small patches of a dark-green chloritic slate are embedded in this rock, running for the most part with the foliation. The slate is evidently much altered and full of shearing planes, which are abundantly coated with the usual greenish products of alteration. This clastic rock contains small lenticular granitite dikes, besides some ill-defined areas of a similar rock somewhat coarser in texture, that doubtless represent squeezed and stretched pebbles and fragments. The hand specimen from which the thin section examined was taken shows a dark-green slaty rock penetrated by tongues or dikes of a dark-red felsite. Under the microscope the dark-green portion is seen to be a typical clastic rock with subangular and rounded fragments of orthoclase, plagioclase and quartz embedded in a finer-grained groundmass composed chiefly of epidote and chlorite, which have doubtless resulted from the mutual reaction of the feldspar and bisilicates originally present. Sphene in irregular grains, and some pyrite, were noted scattered through the section. The little tongues or dikes of felsite are seen to be composed of orthoclase and quartz chiefly, together with some plagioclase. The minerals are much bent, cracked and broken, and have been recemented by chlorite and epidote. The whole rock has been profoundly sheared and has evidently been derived from a fine-grained greywacké formed from the degradation of a granite, this rock being subsequently penetrated by the fine-grained felsite dikes. These dikes are all intensely shattered, and the feldspar affords beautiful examples of twinning striations resulting from pressure. The cracks are filled with sericite, chlorite and epidote.

On the shore southeast of the island in the northern part of Moxam lake the gneiss is very evenly foliated by the alternating sequence of massive red feldspathic layers, which in themselves show marked parallelism, and dark-green chloritic bands, the whole dipping S. 47° E. $<$ 75°. A few chains to the northeast the ordinary greyish granitite-gneiss with very even foliation dips S. $<$ 40° E. 40°. At a point on the east side of the lake a little over an eighth of a mile from the outlet there is a dark-green distinctly bedded rock (greywacké) associated and interfoliated with bands and irregular patches of the massive reddish granitite-gneiss intrusive through it. The rock resembles very closely a highly altered feldspathic sandstone, when broken phenocrysts of feldspar were noticed embedded in the greyish groundmass. The strike of the foliation is N. 13° W. and dip N. 77° E. 70°.

On the opposite side of the lake also the dark-red massive granite-gneiss contains a good deal of the highly altered greenish-grey slaty rock. At the lower end of the portage going north from Moxam lake the usual reddish granitite-gneiss occurs, striking N. 30° W., and dipping east < 50°. Apparently caught up in the mass of this gneiss are some patches of dark-grey slaty rock, very much hardened and altered and beautifully banded by the occurrence of layers rich in yellowish-green epidote. To the north of this, almost in the bed of the stream, are outcrops of similar gneiss containing many dark-greenish bands composed chiefly of chlorite and epidote. They doubtless represent portions of highly altered clastic material and associated with these are some larger irregular patches of undoubted feldspathic sandstone. These smaller interfoliated bands have evidently undergone extensive recrystallization, thus masking their original structure, but this stratified appearance is in marked contrast to the intrusive aspect of the granitite-gneiss. The foliation, produced essentially by pressure, has a strike of N. 2° W., and a dip easterly < 65°. A little north of the mouth of this creek outcrops of the massive red granite-gneiss contain squeezed fragments of clastic material often of very irregular outline, the strike of the whole exposure being N. 21° E.

On the east side of the small lake below Moxam lake a rock composed of alternating folia of red and dark-green material was seen striking N. 2° W., and dipping to the east at a high angle. A similar rock outcrops at the southern end of Glasford lake, the strike being N. 9° W., and the dip towards the east < 60°. The hand specimen examined showed a foliated rock consisting of a fine-grained chloritic groundmass of a dark-green colour, through which runs irregular wavy tongues of a bright red, fine-grained felsitic-looking rock. In its microscopic character it bears a marked resemblance to the rock occurring on the west shore of Moxam lake, but in the case of the chlorite which is abundantly developed throughout it, its origin is plainly seen to be from hornblende (cores of this mineral occurring surrounded by the chlorite.) The feldspar is very turbid and is stained throughout by oxides of iron; a bright yellow, strongly pleochroic epidote is very abundant in the section.

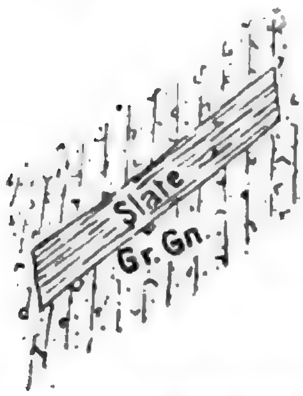
The southern part of Glasford lake is occupied by the massive red gneissic granite which seems to be composed chiefly of flesh-red feldspar and greenish chlorite or hornblende, or perhaps both. The strike curves around from north to northeast with an easterly to southeasterly dip 45° to < 60°. This is followed by a compact greyish slaty rock with granite inclusions, some of which are pebble-like in outline and appearance, while others evidently represent approximately parallel small lenticular intrusive dikes of the neighbouring granitic rock. This characterizes the shore for nearly a quarter of a mile, and may represent a tongue or extension of the main mass of similar Huronian strata to the southwest.

To the northward it may be continuous with an outcrop of breccia-conglomerate that occurs on the west shore of Cooper lake, near its southern end. The northern part of Glasford lake is occupied by massive red granitite-gneiss, with which is associated some greenstone, such areas seemingly representing the primary or first formed secretions from the same magma, the cooling of which produced the associated granitite-gneiss. From this to the second little expansion below Glasford lake gneiss is the prevailing rock, the strike being N. 19° E. At one point in the narrows this gneiss contains bands and small irregular inclusions of a dark-green hornblendic rock. The inlet into Cooper or McDonald lake is occupied by a massive red and reddish-green, often porphyritic, granitite-gneiss, striking N. 3° E. and N. 11° E., and dipping to the east at high angles.

The shores of Cooper lake are occupied chiefly by a flesh-red granitite-gneiss, in some cases porphyritic, weathering greyish, especially when burnt over. The foliation, which is not very apparent in places, is sometimes brought out more strongly by the more or less parallel alignment of certain ill-defined patches of more basic material. The rock is composed essentially of flesh-red feldspar, chiefly orthoclase, and more or less greyish quartz, this latter material being often present in vein-like streaks and patches, evidently pegmatitic both in origin and structure. The little ferro-magnesian material present is apparently biotite, which has undergone somewhat advanced chloritization. This is associated with a massive medium-textured greenstone, the irruptions of the two rocks evidently being very closely synchronous. The prevailing strike of the foliation, wherever apparent, is from northeast to southwest. On the west shore of the lake, south of the narrows, a patch of the dark greenish-grey breccia-conglomerate comes in, apparently forming a huge mass caught up during the intrusion of the granite. It contains the usual pebble-like and other forms of granitic material, while the matrix in which these are contained has the customary dark greenish-grey colour. This rock occupies the shore for about an eighth of a mile. The contact between this clastic and the red granitite-gneiss to the north is irregular and ill-defined, irregular dike-like forms and patches of the latter penetrating the mass of the slate. The bedding of the slaty rock abuts on the dim foliation of the gneiss, the slate striking N.N.W., while the direction of the foliation of the granitite-gneiss is southwest.

This patch of slate is interrupted to the south by a red, very feldspathic, granite, which continues along the shore for about six chains, when it in turn gives place to the dark-greenish slaty rock, similar to the mass already described, which occupies this side of the lake to its southern extremity, where the low ground conceals the rock beneath. These masses may either represent detached portions of the clastic Huronian strata caught up and floated off during the intrusion of the association granitite, of whose irruptive character there cannot be a doubt; or, on the other hand, they may belong to a band or tongue co-extensive with the main mass of similar clastics to the southeast, but whose continuity at the surface is broken or concealed by the dense forest growth. The island in the narrows of this lake, as well as the west end of the comparatively large island to the north, is composed of a greenish-grey greenstone or diabase. At the outlet of Cooper lake the foliation of the prevailing granitite-gneiss is marked by the parallel disposition of plates and aggregated patches of chloritized biotite. It is sometimes rather obscure, and the rock is very massive and granitic in character. The strike is N. 3° E. Embedded in this gneiss and crossing its foliation is a rudely rectangular mass of a greyish slaty greywacké. The mass is about two feet wide by about fifteen feet in length, the direction of its longer diameter being about northeast, while the foliation of the gneiss is only a few degrees east of north.

Fig. 5.



The rough and bouldery stream which separates Cooper lake from the Matabitchouan river shows outcrops of the massive reddish gneiss, the strike apparently being about N. 13° E. At a narrow gorge, through which the stream runs, a patch of greenish chloritic and epidotic schist was noticed embedded in the intrusive gneiss. The hand specimen showed a dark-green, rusty-weathering, compact, foliated chloritic rock, with numerous minute particles of pyrite scattered through it. The microscope shows it to be a typical epidotic and chloritic schist in which all traces of the original structure have been destroyed. It bears a close resemblance to those described by Dr. F. D. Adams, from the Eastern townships,* and consists of a schistose aggregate of feldspar, quartz, pale-green chlorite, epidote and pyrite. The epidote is in granules of varying dimensions, and also in crystals, which present sharply defined rhombic sections. It is strongly pleochroic. The chlorite forms pale-green folia, running through the fine-grained mosaic of quartz and feldspar forming the groundmass of the rock. Many of these schists have been proved in other regions to have resulted from the shearing of a basic eruptive, and it is quite possible that this rock has had just such an origin, but, on the other hand, taken in conjunction with the other occurrences of very similar, though perhaps less altered patches of stratified material just described as having been caught up in the gneiss, it probably represents a completely recrystallized basic greywacké-slate.

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*Report of progress Geo. Surv. Can., 1880-2.

Between this point and the Matabitchouan there is only another rock exposure consisting of the breccia-conglomerate, situated on the west side of the small bay into which Macdonald creek discharges, and about thirty chains to the southeast of the main channel of the river. The junction, therefore, between the granitite-gneiss, here constituting the Laurentian, and the slaty breccias of the Huronian may be put down with tolerable accuracy as running across the southeastern end of this small bay.

OTTERTAIL CREEK.

Ottertail creek (Nikig-wai-no-wai-sipi) rises in a number of small streams, draining the extensive swamps that occupy the greater portion of the northwestern corner of the township of Hammell, as well as nearly the whole of the timber limit 21 E. situated to the north of this township. The main branch of the creek may, however, be stated to take its rise in a small swampy lake, situated in the fifth concession of the township of Hammell on the line between lots 8 and 9. The distance from its mouth, nearly four miles north of the Opimika narrows on Lake Timiskaming, to this small lake, is about twenty miles in a straight line bearing S. 50° W., but following the bends of the stream this distance is increased to a little over thirty miles. The most important branch, however, forming as it does a portion of the route occasionally used by travellers to reach the interior, takes its rise in a small beaver-pond a short distance north of the northern boundary of timber limit 12 E. This pond is separated by a portage of only a quarter of a mile from another small expansion known as Bush lake, that flows into the Martin river about three-quarters of a mile southwest of the inlet from Mackenzie lake. The distance from this small beaver-pond to the mouth, following the course of the stream, is twenty-two miles and a half, but in a direct line, bearing S. 71° W., it is only a little over sixteen miles.

The first portage on the route inland by way of this stream starts from Grenier's clearing, a short distance north of the mouth of the stream, and is a little over a mile in length. It runs from the valley over the high hills that border Lake Timiskaming. The upper portion of these hills shows the usual hummocky outline which elsewhere occurs with extended exposures of the reddish gneiss. This rock is massive and granitoid in appearance, but distinctly foliated, the strike being to the northeast while the dip is to the northwest < 65°. The highest point on this portage is 365 feet above low water on Lake Timiskaming, while the creek reached by the west end of the portage is 180 feet above the same datum. The descent, therefore, towards the creek, though less (285) than that towards the lake, is very abrupt and steep. Four more portages intervene before the lake at the forks is reached, these showing a combined fall of nearly eighty-four feet. The portages are all on the northeast bank of the river and are short, the longest being a little over half a mile. These are to overcome low rapids caused chiefly by bouldery obstructions. Between these rapids the creek is comparatively deep and about twenty yards in width. flowing with a gentle current between banks composed of coarse, yellowish sand. The rock, wherever exposed, is the common granitite-gneiss, very massive and granitoid in structure, but with distinct foliation, striking N 30° E., and dipping to the northwest <65°.

The main forks, where the north branch joins the main stream, is about four miles from the mouth, the creek throughout this distance having a general course of N. 76° W. The lake at this fork represents in reality the last stretch of the north branch before it enters the main stream. The name Wabamik, by which it is known to the Indians, refers to the legend that a huge white beaver formerly lived on its shores. The immediate banks of the lake are for the most part low and marshy, but two exposures of rock which were noticed resembled the massive reddish granitite-gneiss striking N. 35° E., and dipping to the southeast < 70°. A few hills rise to the south of the forks, but at a considerable distance away from the creek, while the valley of the creek immediately above is wide and level. To the southwest of the lake a rather prominent hill rises in close proximity to the shore, while to the northeast the numerous rounded rocky ridges of the usual flesh-red granitite-gneiss rise from 200 to 250 feet above White-beaver lake.

Between the forks and the intersection of the Lake Timiskaming colonization road the distance by the stream is about eleven and a half miles. In this distance there are nine portages, to overcome as many rapids and chutes. Seven of these are low rapids where the stream is obstructed by boulders, while two are chutes, the channels being comparatively narrow and cut for the most part along the strike of the foliation of the gneissic rock. The intervening stretches of quiet water, between these interruptions to navigation, average nearly a chain in length, the water being tolerably deep, and the banks on either side fringed with a dense growth of alder and willow. The stream in many places pursues a rather tortuous course through the narrow sandy flat, although some of the more prominent bends reach the solid rock on either side of the valley.

At the first rapid above the forks the stream falls about ten feet through a gorge excavated in flesh-red granite-gneiss, well foliated and laminated and striking N. 38° E., while the dip is to the southeast $< 45°$. The gorge or cañon runs for the most part with the foliation, but at one place it breaks across the strike of the gneissic-rocks. At the lower end of the third portage the gneiss is the dark-grey, almost black, variety, which is at once hornblendic and micaceous, and to which the name quartz-mica-biotite has been applied. It is a glistening evenly foliated gneiss stained in places with iron oxide. The strike at this place is about northeast, thus corresponding with the general trend of the stream. Under the microscope the rock is seen to be composed of plagioclase, orthoclase, quartz, hornblende and biotite with sphene, apatite, zircon, pyrite and limonite as accessory minerals.

At the sixth portage (made to overcome a rapid which also flows through a rocky gorge cut out along the strike), the rock is dark-grey and micaceous, well laminated as well as foliated and striking N. 22° E. with a dip to the southeast $< 45°$. At the seventh portage the rock is the fine-grained reddish granitoid variety, doubtless a granitite-gneiss. Between the bridge on the Lake Timiskaming colonization road and the forks with the main branch above there are three obstructions in the stream. Two of these are caused by boulders, but the third, which is intermediate between the other two, shows a descent of nearly thirty feet with a portage on the south side. The rock at this place is massive and much jointed, and represents the prevailing red-granitite-gneiss. At the third rapid above the bridge the rock present is massive, rather fine-grained, reddish in colour and distinctly gneissic in structure. The thin section under the microscope shows it to be a granitite-gneiss, composed of orthoclase, plagioclase, microcline, quartz, biotite and primary epidote, the orthoclase being by far the most abundant constituent. The accessory minerals noted were apatite, zircon and sphene.

A short distance above the rapid the surface of the country flattens out, while the creek itself, for a distance of over two miles, pursues a tortuous course through an extensive beaver-meadow, and numerous beaver-dams obstruct navigation. It is expedient to make one long portage avoiding this portion of the creek and coming out at the southeast end of Ruth lake. Ruth lake, and the beaver pond beyond, marking the head of the Ottertail in this direction, are practically on the same level, and the portage connecting them runs on the southwest side of the creek. On this portage some birches, over nine inches in diameter, which had been felled by beaver, were noticed. The strike of the rock in Ruth lake is about southwest. It shows the usual alternating reddish and greyish bands which, in themselves foliated, give by their even and parallel disposition not only a very marked foliation, but a distinct lamination to the whole mass. Under the microscope a specimen obtained from the northeast shore shows the rock to be of the variety here designated granitite-gneiss. It is composed of orthoclase, microcline, plagioclase, quartz-biotite and primary epidote with apatite, zircon, sphene and a little iron ore as accessory minerals.

From Ruth lake a portage a little over a mile and a half in length runs to Fanny lake, at the headwaters of one of the tributaries of the Martin river. The southwestern end of the portage passes over a somewhat low, though in places rocky tract, grown up with small trees. There is little soil, and the rock, when exposed, was seen to represent red and grey banded granitite-gneiss. The last half-mile near the northeast end of the portage approaching Fanny lake is over lower land, very marshy in places.

The portage from the beaver-pond to Bush lake is about a quarter of a mile in length and the barometer showed the latter to be ten feet lower than the beaver-pond. The shores of Bush lake are comparatively high and for the most part rocky. A hill rises close to the southwest shore of the lake to a height of about 150 feet. The rock which is frequently seen is a granitite-gneiss, well foliated, but somewhat massive and granitoid in structure. The strike is N. 45° E. and the dip southeast $< 50°$. The portage from Bush lake to the Martin river, into which it empties, shows a fall of about forty feet. The trail starts from the northeast side of the creek, but crosses over to the southwest side. It shows evidence of having been but slightly used. Indeed the whole route inland by way of Ottertail creek is but little known and therefore rarely used, and as the beavers have been nearly all exterminated in the vicinity of its banks it has been but little frequented of late years for hunting purposes. Occasional beavers, however, still reside along the course of the creek, as abundant work done quite recently showed.

Bay lake to Lake Timagami, by way of Annima-Nipissing, Carrying, and Red Squirrel lakes.

This route commences at a small marshy bay on the southwest side of Bay lake, about one and three-quarter miles southeast of Bay Lake post. The narrow and crooked, though navigable channel of the small inlet that enters the lake at this point is followed a short distance to the foot of the portage. The portage is in reality a winter road, built in 1881 by Father Paradis to take in supplies from Bay lake to Timagami, and is a little over one mile and a quarter in length of almost continuous climbing, reaching Annima-Nipissing lake at the extreme northeastern corner. The trail follows up a valley, which, as the summit is approached, becomes very narrow, the hills of quartzite-grit on either side approaching each other very closely, while a talus of angular blocks detached from the heights above still further obstructs the narrow pass. At the summit a sort of *cul de sac* occurs, the steep slope facing towards Bay lake, but once this sharp incline of fifteen feet is surmounted there is a gradual descent of about ten feet to Annima-Nipissing lake. This lake is about one hundred and eighty feet above Bay lake or 1073 feet above the sea, while the highest point on the portage, only a short distance from Annima-Nipissing lake, is only ten feet higher.

Annima-Nipissing or Aminipissing lake, (the name meaning the head of the Nipissing waters), runs in a general direction of S. 30° W. for nearly ten miles. It is separated from McLean lake, to the southwest, by a small narrows, containing a rapid, and which, although showing a decrease in level of about two feet, is sometimes described as forming part of the larger expanse. This important sheet of water is divided into three portions, separated by two narrows. The most northerly of these stretches has a length of four miles and three-quarters and varies from a quarter of a mile to a mile in width. The central portion is much smaller and presents a much more irregular outline. One of the bays running to the southeast affords an entrance to an inlet from Breeches lake, on the road to Mountain lake, at the headwaters of the main branch of the Matabitchouan river. A somewhat longer arm running a little west of south approaches very close to the waters of Mannajigaina lake, while still another extension, running to the northwest, receives the small creek from Pickerel lake, from which it is separated by a portage only a few chains in length.

The southern part is about three miles and a half in length and is over half a mile wide. It likewise has an irregular shape, a large bay running to the northwest for nearly two miles from the northern end of the stretch. About a mile and a half from the outlet into McLean lake a small stream enters, forming the outlet of Whitewater and Diabase lakes. Several soundings were taken in places reported to be exceedingly deep. One of these places, situated about the middle of the lake, opposite Crow rock and a little over a mile from its northern end, showed a depth of ninety-three feet, while another sounding, taken about the middle of the large open space in the central part of the lake, gave 100 feet. The water has the clear and limpid character and light sea-green tint of Timagami, although in point of clearness and purity both these lakes are excelled by Whitewater lake, lying to the west of the southern part of Annima-Nipissing lake.

The coarse quartzite-grit or arkose occurring on Bay lake extends to the tract passed over by the portage entering the north end of Annima-Nipissing lake. It also extends down the eastern shore of this lake for nearly three-quarters of a mile, when it gives place to a coarse gabbro that occupies the shore for over a mile farther south. The rock, as here exposed, is rather coarse in texture, and is characterized by the presence of reddish feldspar, in this respect resembling certain portions of similar irruptive masses to the northwest of Bay lake, as well as at Quinn point on the east shore of Lake Timiskaming. Near the line of junction with the gabbro the quartzite has been considerably altered by its intrusion, the alteration consisting chiefly in a hardening due to the secondary enlargement of the original quartz grains and the deposition of interstitial silica. On the west side of the lake this arkose forms a perpendicular cliff about a hundred feet in height, known as Crow Rock, and, continuing down along this shore occupies the greater part of the southern shore of the bay running to the southwest. The large island, as well as the much smaller one to the northeast, is composed of massive greenstone or gabbro, but the island lying close to the shore to the southwest of these is formed of the slaty greywacké, underlying the arkose. On the point to the southwest of the large island a considerable inlier of banded slate appears to have been caught up in the mass of the greenstone during its irruption, and the bedding of the slate, well marked by the alternating colour-bands, shows an inclination N. 50° W. < 15°.

The relative distribution of the greenstone and slaty greywacké, the latter being the prevailing clastic rock, is shown on the map. The diabase gabbro forms a series of high hills which are in marked contrast to the flat topography characteristic of the areas underlain by the slates. On the west side of the lake this greenstone sometimes forms the shore-line, while elsewhere it is replaced by a strip of the slaty greywacké only a few chains in width. The clastic rocks in this portion of the lake have a prevailing dip to northeast or north-northeast at a low angle, usually less than 10°. The southern and southeastern shores of the central portion of the lake show somewhat extended exposures of greenstone, both gabbro and diabase being present in the same mass. To the south these rocks seem to merge gradually (through a massive greyish or pale-pinkish gneissic granite well exposed on Mannajigaina lake), into the mass of flesh-red granitite and granitite-gneiss that prevails over such a large area to the south and southwest. The field relations of these several rock-types seem to furnish considerable proof that all three have originated from the same magma, differing only in their rate and manner of cooling. The irregular point of land on the northwest side of the lake, between its northern and central portions, as well as the extreme point on the east side of the narrows, is composed of rather flat-lying slaty strata. On the west side of the southern stretch of Annima-Nipissing lake is a range of hills composed of irruptive material, chiefly a rather coarse-grained granite.

Closely associated with the last-named rock is that to which the name breccia-conglomerate has been applied in this report. The matrix is, in general, a dark greyish-green chloritic and epidotic greywacké, enclosing numerous fragments of various irruptive rocks, those of flesh-red granite being the most abundant. These are often quite angular in outline, occasionally showing re-entering angles, although usually they possess a more or less perfect rounded outline. These larger fragments include pieces of flesh-red feldspar and greyish quartz or quartzite, red and reddish-grey granite, fine and medium-textured diabases and sometimes diorites of several species. Occasionally fragments of a greenish slate, apparently identical with some classified as Huronian, were also noticed. This coarse material is occasionally so abundant that little of the finer matrix is represented, while, elsewhere, only an occasional pebble or fragment was noticed, the rock passing upward into a distinctly banded slate, which is usually entirely free from such inclusions.

The greater portion of these hills is composed of a very pale flesh-coloured granite, which is associated with and apparently merges into a greenstone or diabase. One point shows a prevalence of the granite with bands and patches of the greenstone scattered through it, while other outcrops, not very remote, exhibit a preponderance of the greenstone, with irregular dike-like forms of granite penetrating it in all directions. Both granite and greenstone invade the breccia, while fragments of the latter are caught up in both of these intrusives. The contact between what is evidently a pyroclastic rock and the igneous intrusives is a curious wavy line, which in places can be laid down with exactitude, while a short distance away there is apparently a commingling of the two rocks through fusion, that causes a seeming transition from one to the other. The history of the formation of these several rocks would seem to indicate that the granite and greenstone represent differentiated irruptives forming the original deep-seated portions of an old centre of volcanic activity, which subsequent erosion and denudation have exposed at the present surface. The breccia-conglomerate, on the other hand, doubtless constitutes the lower portion of the associated volcanic breccia, formed by the accumulation and consolidation of portions of the various strata rent asunder during the progress of the eruption, this resulting pyroclastic material being spread out upon the bottom of a shallow ocean, where it has become rolled, sorted, and possibly mixed with ordinary aqueous sediments. The overlying slates show very little sign of aqueous abrasion, while in their composition and appearance under the microscope they closely resemble fine-grained tuffs, representing the consolidation of the first volcanic ash beds.

Whitewater lake (Kawabish-kagama) is an irregular sheet of water running in a general direction of a little north of west for about three miles. It empties from the west into Annima-Nipissing lake about one mile and a half northeast of the outlet into McLean lake. A short portage, over exposures of breccia-conglomerate, follows to the north of the discharging creek. A belt of diabase runs from the western shore of Annima-Nipissing lake to the south of this lake, forming the points of the small peninsulas near the west end of the lake, and connecting with the large mass of similar rock to the west and north. The clastics associated with this greenstone include the massive dark-greenish-grey greywacké with or without large enclosed pebbles and fragments. Diabase lake, about a mile in length, is separated from Whitewater lake to the south, into which it empties, by a short portage, and, as its name implies, is completely enclosed by greenstone that to the northwest of the lake rises into considerable hills. Gull Rock lake is reached by a portage considerably over half a mile in length from the northwest end of Pickerel lake. It is so shallow that the Indians assert that during severe winters it is frozen solid to the bottom. Its outlet, leaving the northwest angle of the lake, flows into the Montreal river a short distance below Pork rapid. It is completely surrounded by low hills of the coarse quartzite-grit or arkose.

Mannajigaina (Ugly-running) lake and Snake lake (Nakwaganak) lie a short distance to the southeast of the southern part of Annima-Nipissing lake, the former being reached by a portage about thirty chains in length, running from the extremity of a bay on the east side of Annima-Nipissing lake, about two miles and three quarters from its outlet to McLean lake. The shores and islands of Mannajigaina lake, which runs west for about two miles, are composed of a greyish and pale flesh-coloured gneissic granite, the foliation, though at times somewhat indistinct, being nearly always discernible. Snake lake, the lower of these two expansions, is also surrounded by a very similar intrusive rock, with the exception of the southeastern corner, where a comparatively large patch or area of the breccia-conglomerate is exposed. The immediate shore-line, on this side of the lake, is occupied by a narrow strip of granite, while immediately to the south the breccia-conglomerate forms a rather high hill, with a dip to the south < 8°. The contact between the breccia and the granite is at times very sharp and distinct, when it exhibits a curved or sinuous line, but at other times there is a narrow brecciated zone, caused by the invasion of the breccia by the granite and the inclusion of fragments of the former in the latter.

The eastern shore of the southern part of Annima-Nipissing lake is composed of the dark greenish-grey greywacké-slate, containing fragments and pebbles of granite and other irruptive rocks. The slaty rocks characterize a band on this shore varying from an eighth to a quarter of a mile in width, while the southeastern part of the two small bays that indent this shore-line show continuous outcrops of a flesh-red gneissic granite. On the south shore of the more northerly of these two indentations the immediate contact between the granite and the slates was noticed, the latter rock dipping N. 50° W <50°, while the foliation of the granite has an inclination S. 87° E. <70°. At the foot of the more southerly of the two bays the foliation of the granite-gneiss has a strike of N. 47° E., and a dip to the northeast <45°.

The greater part of the northwestern shore of McLean lake is composed of very much squeezed and altered chloritic greywacké-slate. This likewise occupies the points on the southeastern shore, but the granite-gneiss crops out all along the bottom of the bays as well as along the sides towards the south and southeast. The portage from McLean lake to Carrying lake (Kecheonai) is nearly thirty-five chains in length, and the rock, abundantly exposed, is a coarse flesh-red gneissic granite, the foliation being marked by the parallel disposition of chloritized scales of biotite. In composition the rock is a granitite, being composed chiefly of orthoclase, quartz, biotite decomposed to chlorite, with smaller quantities of epidote and sphene. The strike of the foliation on Carrying lake is N. 42° E., with a dip to the southeast. The contact between the granite and the breccia-conglomerate runs across Carrying lake near its centre, the clastic rock having a strike of N. 72° E., and dip to the northwest <60°.

The portage into Red Squirrel lake (Atchimo) is over half a mile long, and shows, at the beginning, exposures of breccia-conglomerate. Outcrops of the same rock are very abundant on Red Squirrel lake, and on one of the small islands the granitic and diabasic fragments and pebbles are so abundant that very little of the dark-greenish chloritic matrix can be seen. On the southeast side of the lake this rock rises into hills about three hundred feet in height, dipping S. 17° E. < 45. To the west and southwest of Red Squirrel lake steep hills of diabase rise to a height of nearly four hundred feet above it. The portage from Red Squirrel lake runs to a small marshy expansion of the Annima-Nipissing river, starting from the end of a small bay on the west side in which is the outlet.

The trail is about fifty chains in length, crossing the Annima-Nipissing river or outlet by means of a small rocky island about a quarter of a mile from the lower end. The rock at this point is the prevailing breccia-conglomerate containing chiefly granite fragments. Between Red Squirrel lake and the crossing of the river the portage passes over a sharp and steep esker-like ridge of sand that runs about north-and-south, corresponding with the direction of ice-flow in this locality. From the foot of the portage it is nearly three-quarters of a mile down the stream to its mouth on Sandy inlet at the north end of Ferguson bay on Lake Timagami.

SHARP ROCK INLET (TIMAGAMI) TO MATTAWAPIKA (MONTREAL RIVER.)

Nonwakaming and Lady Evelyn lakes, which occupy this interval, have of late years become rather well-known topographical features, as they form a considerable portion of a favourite canoe-route between Lakes Timiskaming and Timagami, commencing at the long portage which runs from Haileybury post-office to Sharp lake. The distance by the Haileybury route, following Sharp and Mud lakes and the Montreal river, is about seventy miles, to the Hudson's Bay Company's post on Bear island in Lake Timagami, while from the mouth of the Matabitchouan river on Lake Timiskaming to the same place the distance is only forty-three miles following the canoe channel.

The first portage from Lake Timagami to Nonwakaming lake is about a quarter of a mile in length and is situated on the northeast side of the stream, which, during the earlier months of summer, only serves as a northern outlet of Lake Timagami. The trail is strewn with angular fragments of the subjacent light-green banded slate, this fact having suggested the name of "Sharp-rock portage," by which it is known. Nonwakaming lake is sometimes also called Diamond lake. The first-mentioned name is of Chippewa derivation, referring to the fact that five portages afford an exit from the lake in as many different directions. These include, first:—one running to the southeasteast towards Lake Timagami. The western bay affords a route going to the southwest towards Wakemika lake and another to the northwest, a long portage connecting the waters of this lake with an expansion that empties into Sucker-gut lake. The two other trails issue from the northern bay, one running northwest to Sucker-gut lake, while the other turns to the northeast into Lady Evelyn lake. From Sharp Rock portage to the route affording an entrance to Lady Evelyn lake the distance is three and three-quarter miles, in a general direction a little west of north, the portage and the outlet of the lake being situated close together on the east side of the lake, about three-quarters of a mile from the end of the long bay that extends in this direction.

The larger part of the area of the lake is an arm running in a direction a little north of west for about five miles with an approximate average width of half a mile, ending in two subsidiary bays, the smaller one running to the northwest, while that to the southwest continues for nearly two miles farther. The eastern side of the lake is flat and the ends of the bays are low and marshy, while the shores along the west side present the steeply-sloping sides of bold rocky hills that come close to the edge of the water.

The rock exposed on the east shore is an evenly banded greenish slate, the planes of cleavage corresponding with those of the bedding. This slate occupies the whole of that shore as well as the two smaller islands close by. In strike it exhibits a gradual curve of N. 20° W., in the southeastern part, to N. 20° E. in the vicinity of the portage going to Lady Evelyn lake; while the angle of dip, always in a westerly direction, changes from 8° in the southern portion to 45° along the east side near the north end. This rock exhibits a transition upward through a more massive dark greenish-grey slaty rock, that occasionally shows the colour-bands so characteristic of the strata beneath, into a compact greenish feldspathic sandstone, which, in turn, merges above in a rather coarse quartzite-grit or arkose. The gradual transition is well shown on the two larger islands situated near the centre of the open space formed by the junction of the several bays. The arkose occurs in very thick beds, generally well jointed, but so massive that, usually, it is difficult to ascertain its true dip or strike. As a rule the rock is of a pale yellowish-green or greyish colour. The fragments usually apparent to the eye consist of a pale reddish or greyish feldspar with a much larger proportion of greyish or colourless quartz, embedded in a matrix composed chiefly of minute scales of yellowish sericite. In places along the north shore of the western bay some of the beds are of a distinct flesh-red colour, being with difficulty distinguishable from ordinary granite, from the degradation of which they have evidently been formed. Under the microscope this phase of the rock is seen to differ from the prevalent greenish type, in that the feldspathic and quartzite fragments are little rounded and accompanied by little sericite.

This quartzite-grit occupies the shores of the western bay of Nonwakaming lake, exhibiting a prevailing dip to the east of northeast <12° to 15°. The small bay forming the southwestern end of the lake shows an intricate labyrinth of narrow channels, separated by small rocky, hummocky or subangular masses of the quartzite-grit, the brook emptying the little expansion to the southwest through a narrow valley of a somewhat similar character. The rocky portage, which is scarcely a quarter of a mile in length, leads to a little lake which is completely enclosed by ridges of the arkose. The trail from this pond to the northwest bay of Wakemika lake is somewhat longer, and passes over ledges of the quartzite-grit. Wakémika lake is a little over three miles in length, and the main portion shows a width of over two miles. The northeastern bay is almost completely separated from the rest of the lake by two opposing ridges of sand which leave a very narrow intervening channel with a gentle current. A considerable bay on the western side of the lake is formed by the projection of a long narrow point or peninsula from the southern shore. The outlet of the lake is into Obabika lake about two miles distant to the southeast, with only two intervening portages. The lake has been excavated for the most part in the massive or upper part of the prevailing banded slates, that here dip N. 75° E. <12°. At one place on the south shore this slate is seen to have developed a perfect cleavage, striking N. 20° W., and dipping west <80°. These slates show the usual transition upward, through a narrow belt or zone of fine-grained greenish feldspathic sandstone, into the coarse-grained light greyish-green arkose, whose massive beds dip to the east < 15°. The eastern shore of Wakemika is composed of the same arkose dipping east <12°. These quartzite-grits on the east side of Wakemika lake, as well as those forming the shores of the western portion of Nonwakaming lake, occupy the upper part of a low synclinal basin, resting conformably upon the slates and slaty greywackés exposed on the southern shores of Wakemika lake and on the eastern side of Nonwakaming lake.

On the west side of the northern bay of Nonwakaming lake the greenish arkose is overlain by a greenish vitreous quartzite, very much sheared and broken, the pressure and fracture planes being coated with brightly glistening scales of yellowish-green sericite. The rock is made up almost wholly of greyish translucent quartz with a lesser proportion of feldspar, some of which has been converted into this hydrous form of muscovite by dynamic action.

The portage from Nonwakaming to Lady Evelyn lake is about twelve chains in length, and is used to avoid a chute and rapids below with a total fall of about twenty-five feet. Lady Evelyn lake (so named in 1888 by Dr. Bell) is known to the Indians as Muskananing (the haunt of the moose). It measures nearly twenty-two miles in length from the portage entering the south end to the rocky obstructed chute which marks the outlet into the Montreal river. The trail reaching the south end shows exposures of greenish slate, containing coarser interlaminated beds of a fine-grained greenish-grey feldspathic sandstone, all having a distinctly bedded character. These partings of greywacké, which vary from a few inches to a foot or even more in thickness, weather to a pale-purplish colour. The strike changes from N. 40° E. to N. 20° E., the various exposures showing marked evidences of considerable tilting and dislocation; the angle of inclination being unusually high, from 38° to 53° in a northwesterly direction. For three miles north of this portage the lake is narrow, being for the most part either obstructed by the loose masses of the prevailing slate or cut up into a number of channels by a series of small islands.

The general trend of the shores, on either side, corresponds rather closely with the strike of the enclosing slates which is N. 20° E., while the dip is in a direction of N. 70° W. $<5°$ to 10°. The hand specimen collected as typical of the rock occupying this interval is a light greenish-grey fine-grained felsite, of which the jointage planes are coated with hydrated peroxide of iron, while the weathered surface exhibited a pale flesh-red tint. A thin section shows the rock to be composed of orthoclase, quartz and plagioclase, the first-named mineral being the most abundant, while only occasional individuals of plagioclase were noticed. The fragments are very uniform in size and show little or no interstitial matter. They are angular or subangular in outline, frequently interlocking with one another. The section evidently represents a clastic which has suffered little from aqueous abrasion, while subsequent incipient recrystallization has concealed, in many instances, some of the rounded outlines due to the action of water. Irregular scales and plates of chlorite are present, as also a small quantity of iron ore, the abundance of the former giving to the whole rock-mass its decided greenish colour.

About three-quarters of a mile to the south of the large opening that constitutes the main body of the lake these fine-grained feldspathic sandstones or felsites are interrupted by a mass of medium-textured diabase that crosses the lake. Northward it extends along the east shore for a distance of over four miles, being succeeded in this direction by a compact fine-grained greenish greywacké that dips to the west $< 10°$. On some of the islands lying near this shore a beautifully banded or foliated tufaceous rock was noticed which is intimately associated with the diabase. The latter likewise occupies the southwest shore of the main body of the lake, and also the three large islands in that neighbourhood, as well as a small strip on the western side, the continuity of the mass being broken by the appearance at the coast of an area of very vitreous pinkish or greyish quartzite which dips to the west <45°

For the next succeeding six miles the lake has an average width of over two miles, while it is sometimes as much as three miles. A chain of islands, however, that runs up the centre, as well as a considerable number of islands, both large and small, near the eastern side, conceal much of its true size. The islands in general are low and have a somewhat irregular outline. Those in the southern part are composed of a dark greenish-grey feldspathic sandstone, with a decided slaty cleavage, in places corresponding to certain distinctly alternating bands of greyish-green colour, which show a prevailing dip to the east < 5° to 12°. Under the microscope the rock is seen to be a feldspathic sandstone made up of orthoclase, quartz and plagioclase, embedded in an abundant feldspathic matrix, much of which has been decomposed to yellowish-green sericite. This slaty greywacké evidently occurs in a series of low undulating troughs, for on the west shore in the vicinity of perpendicular rocky cliffs a somewhat similar rock is seen dipping N. 70° W. <12°; while still farther north along the same shore the dip is S. 70° E. < 3°. A hand specimen of the rock from these cliffs shows a dark greenish-grey rather fine-grained, feldspathic sandstone weathering to a deep brown colour. Under the microscope it is seen to be composed of angular, subangular or rounded grains of quartz, orthoclase and plagioclase, embedded in a groundmass relatively small in quantity, composed of a confused aggregate of minute yellowish-green sericite scales. Occasional fragments of zircon are present and a considerable quantity of iron ore, some of which is ilmenite, as it is seen altering to leucoxene. A large amount of chlorite is present in irregular scales and plates scattered through the rock, and this, together with the sericite and iron ore, gives the rock its prevailing dark greenish-grey colour.

The islands in the northern part of the main body of the lake are composed of more massive and quartzose sandstones, which, as the Obisaga narrows is approached, assumes more closely the appearance and composition of the prevailing arkose.

On the northeast side of the hill, near Wendabin's house, to the northwest of Lady Evelyn lake, the arkose shows massive beds of a pale flesh-red colour. To the eye the rock closely resembles a granite, but under the microscope its clastic character is clearly seen, and the texture varying considerably in different parts of the section. Quartz, orthoclase and plagioclase are thickly crowded together and are connected by comparatively little sericitic matrix. This can, however, be seen forming at the expense of the feldspar. There has been some enlargement of the grains by subsequent growth, so that in spite of their clastic character they often interlock with irregular sutures.*

To the west of Lady Evelyn lake the country is comparatively flat for a considerable distance, and is composed, for the most part, of a fine-grained, somewhat massive dark, greenish-grey greywacké. This merges gradually upward into the coarse quartzite-grit or arkose that constitutes the range of high hills of which Maple mountain (so called by Dr. Bell in 1888), the highest part, is situated almost directly over the western border of the Lake Timiskaming sheet. Specimens of the rock obtained by Dr. Bell, in his ascent of the mountain from the east side, showed the lower portion of this arkose to be a rock not unlike a rather fine-grained granite. This is interlaminated with small greenish bands in which sericite is relatively much more abundantly developed. The rock was examined by Dr. G. H. Williams and shown to be an arkose sandstone, although the grains are mostly angular and often much fractured. They consist of quartz, orthoclase and plagioclase. Neither mica nor chlorite occur in this section, except as a component of the sericitic groundmass, which is somewhat abundant. Stains of ferric hydroxide are plentiful and impart the reddish colour to the rock. At the High pond on Maple mountain the rock is a pale yellowish-grey quartzite, showing distinct, more or less rounded pebbles, which in appearance closely resemble their matrix. Sericite is also abundant, visible to the unaided eye. The microscope shows this rock to be composed of angular, or but slightly rounded grains of granitic quartz, full of fluid inclusions, which are embedded in a ground-mass of sericite and finer quartz fragments. These quartz grains or fragments differ greatly in size, but are under a millimetre in diameter. Feldspar substance is now rare, although once present it seems under the influence of dynamic action to have passed into sericite or muscovite. In a matrix of this character medium sized pebbles are embedded. These differ from the matrix principally in having a more siliceous groundmass, *i.e.*, they are freer from the sericite. They are, however, coated with a membrane of sericite, as is apt to be the case with squeezed conglomerates or grits. The rock shows distinct evidences of the action of pressure, and the development of its mica is probably due to this agency.*

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*Annual Report Geol. Surv., Can., vol. V. (N.S.), p. 58, F. section No. 25.

*Annual Report, Geol. Surv. Can., vol. V. (N.S.), p. 63 F.

At the Obisaga narrows the pale greenish-yellow or pale flesh-red arkose forms perpendicular cliffs on the south side, a talus of angular blocks lying at the foot. It occurs in thick, massive, much jointed beds dipping to the southwest < 28°. This rock occupies the shore on both sides of the narrows, extending beyond for a distance of about three-quarters of a mile, where it gives place to and is underlain by the banded slate. There is again a gradual transition downward through a massive and compact slaty greywacké into the readily cleavable and thinly bedded, distinctly banded slate beneath. This succession may be well seen on the south shore of this portion of the lake about three-quarters of a mile west of the Obisaga narrows. The prevailing topography of the country to the eastward undergoes a marked change in outline, and from the narrows, known to the Indians as Obashingwakoka, to the point where the lake turns abruptly to the northward, the shores on either side, especially that to the south, are low and marshy, with only hillocks, points and beaches of yellow sand. The lake is correspondingly shallow, with but a narrow channel among water-weeds.

Before entering the portion of the lake known to the Indians as Ko-ko-ko-wa-bikon, and often referred to at the present time as the Mattawapika, (although this name should rightly be restricted in its application to the immediate vicinity of the outlet of the lake) the water is divided into two channels, separated from one another by an intervening low swampy island. The channels on either side are only about thirty feet in width and both of them show a considerable current, which is likewise sensibly felt in some of the shallower and more obstructive portions to the west. A mass of diabase of dike-like aspect crosses the eastern point of the island, forming the rocky barrier broken through by the waters of the lake. The diabase band, (which is an extension to the northward of the large or main mass of similar rock), is about a quarter of a mile in width, and runs parallel to the lake, forming its immediate western shore-line for the greater part of this last stretch before emptying into the Montreal river. This Western side is, as a rule, steep and precipitous, and the basin occupied by the waters of this part of the lake has been excavated, for the most part, along the line of junction between the diabase and the neighbouring slates exposed on the east side. These slates are banded and rise into rather prominent and steep eminences, the beds dipping to the east at low angles. The contact between the two rocks is well exposed at a point on the west shore about one mile and a half south of the outlet. The diabase is distinctly intrusive through the slates, disturbing and altering them, while veins of quartz containing disseminated sulphides fill the irregular fissures formed during the irruption. At the outlet the slates present beautiful alternating colour-bands of greenish and purplish shades running with and indicating the lines of stratification, the dip being to the southeast < 18°. The outlet shows a series of small rocky islets composed of these slates, between and over the outcropping ledges of which the water pitches in a fine cascade about twenty-five feet in height. The presence of this chute with its rocky environment suggested the name Mattawapika, by which this locality is known to the Indians.

LAKE TIMISKAMING (HAILEYBURY P.O.) TO BAY LAKE (ON MONTREAL RIVER.)

From Haileybury, situated on the west side of Lake Timiskaming, in the township of Bucke, to Bay lake, on the Montreal river, there are two alternative routes. The shorter and more direct, by Sharp and Loon lakes to the northeast end of Portage bay, is, however, that least used, chiefly on account of the greater length of the portages. But apart from this the route offers many advantages over the other. The portage from Haileybury (Matabisataganing) to Sharp lake is by a tolerably good wagon-road, a little over six miles in length, that crosses a somewhat flat country, with, however, a general slope towards Lake Timiskaming. The rock beneath is concealed by what seems to be a good depth of soil, composed chiefly of clay, although in the vicinity of Sharp lake there are occasional outcrops of the greywacké slate. The forest growth in this interval is chiefly remarkable for large specimens of both cedar and poplar, probably the finest noticed in the whole district.

Sharp lake (Agwasabanishing) is comparatively narrow, running north-and-south, and a little over two miles in length. The northern portion presents occasional outcrops of the well banded slate, dipping in a northerly direction at an angle not far removed from the horizontal. On the west shore of the lake, in close proximity to the slate exposures at the first narrows south of the portage, and extending for a distance of a quarter of a mile, are outcrops of a medium-textured greenish and greenish-grey diabase, which evidently forms the extension in this direction of the large mass that runs towards Lake Timiskaming and the Montreal river. The southern half of Sharp lake has low sloping shores, which are for the most part densely wooded and show no rock exposures of any kind.

The portage to Loon lake starts from the bay on the west side near the southern end of the lake, and is nearly two miles in length, passing through a level country underlain by coarse sand and gravel. Loon lake itself is only about three-quarters of a mile in length, of a rudely oval outline, exhibiting low swampy shores, composed for the most part of coarse sand with no outcrops of rock. The Indians call this lake Ka-mang-onsiwing. The portage from Loon lake to Bay lake is about two miles and half in length, and also runs through a comparatively level stretch of country, apparently underlain by diabase. A portage between a quarter and half a mile in length separates Sharp lake from Mud lake (Ka-wabijish-keewaga) into which it drains. This is somewhat larger in size than Sharp lake, though very shallow, and has the same general direction. The shores of Mud lake are low, and there is not a single rock exposure throughout the whole extent of the shore-line, which consists of coarse sand and rounded boulders. The portage from Mud lake to the Montreal river is a little short of half a mile, running through a sandy flat between hills of diabase, which rock occasionally outcrops close to the path. To the north and east of Mud lake there are several small lakes, most of which drain northeastwards towards Farr creek. Bass lake is a beautifully clear and limpid sheet of water, and is apparently fed by springs. This lake is almost on the same level with Mud lake, into which it empties, and from which it is separated by a short portage.

The portage to Clear lake, at the head of the west branch of Farr creek, starts from the north end of Mud lake, about an eighth of a mile southeast of that going to Sharp lake, and is over three-quarters of a mile in length. It passes through woods composed chiefly of poplar and soft maple, and over ridges of greenish diabase or gabbro, the summit rising about two hundred feet above Mud lake. Clear lake, as well as the much larger one to the northeast, into which it empties, and which on account of its numerous islands and bays is called Sassaganaga lake, are surrounded on all sides by well wooded ridges composed of diabase and gabbro. Fragments of the banded slate were noticed embedded in the eruptive. Both these lakes and the stream which forms this outlet constitute portions of a route to Lake Timiskaming which is now practically abandoned.

LAKE TIMAGAMI.

This name is of Chippewa derivation, meaning "deep water." Other names, Temagaming, Temagamang and Tamagamingue, often applied to it, are different methods of spelling the same word, while the additional ending "inw" or "ingue" is simply a locative affix denoting "at" or "towards the place of."

In shape the lake presents long and often branching arms reaching out in various directions from a somewhat stunted body. The main part of the lake, which occupies an approximately central position with regard to the different large bays, covers roughly an area of about twenty-five square miles, although the greater portion of this space is dotted with islands, some of which are of large size. The water superficies of the various large arms represent an additional seventy-five square miles, making a total of one hundred square miles. It has a general north-and- south direction, and its greatest length, from the southern end of the southwest arm to the northern extremity of Whitefish bay, is twenty-eight miles and a half in a straight line, although the most direct canoe channel between these two points measures thirty miles. In width, from the western shore to the main body of the lake to the portage running to the Caribou Lake portage, it is sixteen and a half miles in a direct line. The most important of the many bays that form so large a part of this lake, is the Northeast arm, extending from Point Matagama to the Caribou Lake portage, a little over twelve miles, in a direction about N. 60° E., and varying in width from half a mile to a mile. To the south of this, Muddy Water, Cross and Portage bays indent the eastern shore-line, the first-mentioned being about four miles long and half a mile wide. The South arm lies almost directly north-and-south, and is about seven miles in length, from a mile to over two miles in width. The southern and southeastern shores present a series of smaller bays, the largest of which affords an exit to the chief outlet of the lake, a steep rapid known as the Timagami chute, separating these waters from those of Cross lake. The Southwest arm is almost completely cut off from the main lake by Narrows island. The connecting channel to the southeast of this island is very narrow and crooked, while that between the island and the western mainland has a width of a little over an eighth of a mile. From this narrows the bay extends for about three miles, gradually bending around to the south, which trend is maintained for a little over six miles farther, when it branches into two smaller bays, one running to the southwest and the other to the southeast for a distance of about two miles in each case. The width is very variable, in some cases the shores being separated by a distance of over two miles, while in the more contracted portions they usually approach within a quarter or a half a mile of one another.

To the north, the largest extension has been called the North arm, from its general trend. Nearly eight miles north of the Hudson's Bay Company's post this arm is divided into two subsidiary bays, the eastern one being known as Ferguson bay, running towards the inlet from Annima-Nipissing lake, a distance of nearly five miles farther; while the western extension runs a little west of north for about eight miles, being again subdivided at the upper end into two parts known as Whitefish bay and Sharp Rock inlet. The latter portion is almost completely separated from the rest of the lake by Deer and Beaver islands, having narrow and crooked channels at either extremity, in which more or less current is usually discernible, especially after violent winds from the south.

Between the North and Northwest arms there are several minor indentations, known as Ko-ko-ko, Young Loon and Spawning bays. Of these the first mentioned is the largest, running in a direction a little east of north for a distance of about four miles, and receiving at its head the waters of a rather large lake bearing the same name. The Northwest arm (Wuskigama) runs a little west of north, with an average width of over half a mile, for a distance of a little over four miles from Naipaga point, when it changes abruptly to the west, which general course is maintained, with slight deviations, for a further distance of nearly three miles and half.

Like other lakes of the Archæan region this is characterized by great irregularity of its shore-line and by the vast number of islands with which it is filled. These islands vary in size from mere rocks to some which are several square miles in area and complex in form. As shown by the detailed survey of the lake there are over thirteen hundred of these islands scattered over the surface, the main body of the lake, especially, containing a large number.

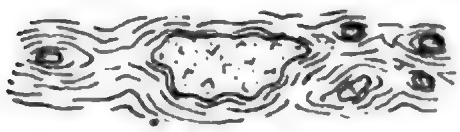
The most important factors that have determined the distribution of land and water are the strike of the foliation or planes of pressure-cleavage and the unequal resistance offered during the progress of erosion by the different varieties of the surrounding rocks. The various bays or arms have been excavated for the most part in the slaty bands, in a direction corresponding with the strike of the foliation; while the shore-lines frequently and for long distances are composed of the hard and unyielding massive diabases or gabbro. As a rule the banks of the lake are high and rocky in many places, especially where the diabasic rocks prevail, rising in cliffs from a hundred to two hundred feet in height. Marshy tracts are few and small, and with the exception of occasional reefs the water is comparatively deep to within a very few feet of the shore. Sandy or shingle beaches are, as a rule, rather rare and of small extent, although at the northern end of the lake, forming the northern shore of Sandy inlet (Kawaminashing) there is a fine sandy shore.

The deepest of a few soundings made, at a point within about thirty chains of the western shore of the main body of the lake, was 167 feet, while another within about half this distance from the same shore showed 127 feet. About mid-channel between Bear island and the group of islands opposite to the west the depth varies from seventy-five to eighty-five feet. Several soundings taken at various places about the central part of the channel of the Northeast arm clearly showed the existence of a deep and practically unobstructed navigable channel to within a short distance of the portage to Caribou lake. The greatest depth was found about a mile southwest of Broom island, 120 feet, while in the centre of the large open space about three miles and a half from the Caribou Lake portage the depth is only ninety-five feet. At the several contracted places along the course of the channel the water is much shallower, the depth opposit the mouth of the Tétapaga lake being only fifty-one feet, while in the narrows, about a mile and a half from the portage, the depth is only twenty-nine feet. The water of the lake is pure and clear and of a light sea-green tint, while the fish, chiefly trout, whitefish, bass, pickerel, pike and ling, are noted for their size and quality.

The clastic rocks exposed on the shores of this lake include at the base the usual and widespread breccia-conglomerate. This rock has already been described, and here presents no unusual features requiring special mention. Here, as elsewhere throughout the region, it passes upward through a massive dark-greenish greywacké or feldspathic sandstone, comparatively free from the larger fragments or pebbles, into a branded slate which is the highest member of the Huronian noticed in the tract of country immediately bordering this lake. Along the Northeast arm the prevailing rock is a light greenish-grey sericite schist containing a great deal of quartz in the form of small lenticular patches and veins running parallel to the foliation. Interlaminated with these hydromica schists are rudely oval patches or masses of a light greenish-grey siliceous dolomite. The quartzose impurities are arranged in narrow vein-like forms which reticulate in all directions through the mass, so that when subject to ordinary weathering processes these stand out in relief, leaving irregular hollow interruptions composed of the softer and more easily distinguished material. One of these masses occurs on the smaller point to the east of the outlet from Hay lake on the north shore, while several were noticed along the lower portion of the outlet from Tétapaga lake as well as at several points along the shore in this neighbourhood. A large mass occurs on some islands a little over half a mile west of the portage into Caribou lake. The sericite schist curves around these ovoid masses of impure dolomite, the latter having been but little deformed by the pressure which has tilted and altered the schists.

These hydromica schists or slates have evidently resulted from the shearing and decomposition of the Huronian slates, due to the close proximity of the two large masses of granite that occur to the north and south of this bay. It seems probable that these two masses of granite are united at a short distance below the present surface, and that the schists, therefore, occupy a comparatively shallow and narrow trough of highly inclined strata which have sagged down somewhat into the originally plastic mass beneath. This supposition best explains the abundance of the quartz veins and masses of pegmatitic or secondary origin, as well as the extreme but uniform alteration of the clastic material, indicating the former presence of an abundant supply of super-saturated and heated siliceous waters and vapours connected with the intrusion of the granite. On Ko-ko-ko bay, likewise, the clastic rocks have in many places undergone extensive alteration, and the pebbles and fragments of the prevailing breccia-conglomerate are embedded in a highly squeezed sericitic or chloritic matrix, which has a flow-like arrangement round the inclusions, caused by the greater hardness of these offering more effectual resistence to the pressure to which the softer matrix has yielded.

Fig. 6.



PEBBLES IN SERICITE SCHIST, KO-KO-KO BAY.

Throughout the whole of the southern part of the lake the numerous and wide exposures, almost without exception, show the granitic and diabasic pebbles and fragments characteristic of the basal breccia-conglomerate; but in some places the massive greywacké occurring above is present, while in occasional localities at the northwest point of High Rock island and the northwestern part of Cross bay the still higher banded slates rise into hills of more than a hundred feet.

The most distinct and persistent structural feature which obtains in the more massive forms of the greywacké and breccia-conglomerate is a pressure-foliation or cleavage. In most places there is little or no sign of stratification, especially in the basal beds, the pebbles and fragments being irregularly distributed in a massive and compact matrix, but the colour bands of the overlying slates are a certain criterion of sedimentation, and these show plainly that the various clastic rocks lie in low, broad undulating folds, dipping for the most part at gentle angles. The development of the foliation seems to have been determined by the pressure exerted during the intrusion of the large masses of irruptive material with which the clastic rocks are so intimately and so frequently associated. The breccia-conglomerate greywacké and banded slates are very evidently graded forms of the same rock, differing only in their relative degrees of coarseness. In origin they plainly represent pyroclastic material, and may be connected generally with the irruption of the massive plutonic rocks, although the clastic rocks have very evidently been disturbed and altered to a certain extent during the progress of their irruption. Such structural relationship is not, however, inconsistent with known facts of contemporaneous volcanic action, the associated volcanic ejectamenta being frequently pierced and altered by dikes and masses of the parent plutonic.

The irruptive rocks present on the lake comprise diabase, gabbro and granite. The diabase and gabbro are usually intimately associated in the same mass, differing only in their structure, which is sometimes macroscopically apparent, but, as a rule, only under the microscope. In composition they are made up chiefly of plagioclase and augite, the latter usually showing incipient alteration to green trichroic hornblende, while occasionally, especially in the vicinity of certain small shrinkage-cavities, the reddish-brown augite is completely decomposed to hornblende that has assumed the actinolitic habit. Usually biotite is present, sometimes in considerable quantity and some allotriomorphic quartz, filling in the interspaces between the other constituents. Ilmenite, showing the characteristic alteration to leucoxene, pyrite, chalcopyrite and pyrrhotite, may also be noticed. A portion of the northeast shore of the main body of the lake presents exposures of coarse flesh-red granitite, forming the extension in this direction of the mass which covers so large an area to the northeast. The rock is exceedingly coarse and massive, often porphyritic, the phenocrysts being mostly Carlsbad twins of orthoclase, often from one to two inches in diameter. The biotite, originally present in small quantity, has been almost wholly converted to chlorite. The whole mass is intersected by numerous, often large, dikes of pegmatite and fine-grained felsite.

In the area immediately surrounding Lake Timagami are several small lakes, some of which are worthy of brief description. The largest of these, Obabika (Rocky Narrows) lake is about fifteen miles long, with an average width of over three-quarters of a mile. The inlet, and the outlet, are situated within three-quarters of a mile from one another, on the west side, near the northern end of the lake. Two short portages, nearly half-way down the lake on the east side, afford an entrance through a small lake into the Northwest arm of Lake Timagami. A short portage separates this lake also from Wawiagania or Round lake, which extends beyond the western boundary of the map, constituting an important link in a canoe-route towards the Sturgeon rapids, and thence to Wanapitei lake. In the northern portion of Obabika lake the rock exposed along its somewhat flat shores is the banded green slate, the light and dark-greenish bands indicative of the bedding dipping E.N.E. < 12° to 15°. Diabase comes out on the eastern shore to the south of the small bay on the route to Lake Timagami, while the breccia-conglomerate in very massive beds outcrops all along the eastern shore in the southern part, and the overlying evenly banded slates at one point on the western shore from nearly vertical cliffs of considerable altitude, with a northwesterly dip < 3°.

The immediate shores of Round lake are low, that on the south side exhibiting a good many low hummocks of slate, with intervening swampy stretches. The western shore to the north of the outlet is formed by comparatively high cliffs, the lower portion of which, up to a height of about fifteen feet above the water, is composed of a green, well banded slate, dipping at a low angle (about 3°) to the west, while superimposed upon this, probably as a sill, is a massive greenish diabase containing abundantly disseminated pyrite. The northern shores show only one exposure of slate, the intervening spaces being low and swampy.

Gull lake (Gyasgosenda), to the west of the main body of Lake Timagami, forms a part of the most direct canoe-route across country to Wanapitei lake. Three different routes may be taken from Timagami to Gull lake. The most northerly is made up of two portages and an intervening small lake; the first portage leaving a small bay on the west side of Lake Timagami, a short distance south of Naipaga point at the entrance of the Northwest arm, while the second portage debouches on the extreme northern end of Gull lake. A second route, and the one most frequently used, consists of a single long portage, which goes up a gully on the west shore of the lake directly opposite the Hudson's Bay Co.'s post, while a third leaves the Southwest arm about two miles southwest of the narrows, and passing through two lakes comes out on the east side of the southern half of Gull lake. The canoe-route thence to the Sturgeon river has seven portages, none of which are of any great length, while the lakes encountered, Turtle, Manito-peepagee and Wawiashkashing, are all of them rather large and important.

On the northwest side of Gull lake the rock is the greywacké slate, while the eastern shore, as well as the southern part of the lake, show outcrops of the massive greenstone (diabase and gabbro). The contact between this irruptive diabase and the associated slates, on the most northerly of the canoe-routes entering Gull lake, comes in near the southwest end of the first portage from Lake Timagami, the dark greenish-grey feldspathic slates in conjunction dipping S. 70° W. < 65°.

From this point the line of demarcation curves around to the southwest, striking the east shore of Gull lake about three-quarters of a mile from the north end. Crossing Gull lake, the islands in this portion of which are composed of slate, it leaves the bay, running to the southwest immediately north of the narrows. To the south, the contact between the greenish feldspathic sandstone and breccia-conglomerate leaving the west shore of Lake Timagami, about three-quarters of a mile south of the narrows at the entrance of the Southwest arm, crosses the first portage on the most southerly of the three routes to Gull lake. Thence, with a southwesterly strike, it cuts across the southern ends of Gull and Turtle lakes, and runs to the east of Manito-peepagee lake, and parallel to its general trend as far as its southern extremity. Here it turns abruptly to the west, crossing the southern end of this lake, and the small lake on the route immediately to the west. The slates and feldspathic sandstone in conjunction with this greenstone are all hardened and otherwise altered in the immediate vicinity of the contact, while the pressure-cleavage which is the only visible structural feature conforms with the line of outcrop of the diabase.

Ko-ko-ko, or Night Owl lake, enters the northern end of a narrow arm or inlet which bears the same designation, running in a northerly direction from the main body of Lake Timagami. The shores exhibit excellent exposures of the breccia-conglomerate on the east side, with which rock is associated an overlying compact feldspathic sandstone. These are penetrated by a massive intrusive greenstone, chiefly diabase in composition and structure, which occurs in a large mass coming out on the northwest side of the lake.

Young Loon and Spawning lakes enter smaller bays off the east side of the main body of Lake Timagami, the latter, together with McLaren, Commanda and Hay lakes, forming a canoe-route, which, with short intervening portages affords a means of communication between this portion of the lake and the Northeast arm, near Broom island. With the exception of Hay lake all are surrounded by hills of a coarsely crystalline flesh-red granitite, composed chiefly of flesh-red feldspar, greyish-white quartz and a sparing quantity of chloritized biotite. Occasional exposures are rather fine-grained, and contain proportionately a greater amount of the coloured constituents, while, on the other hand, the coarser-grained material is almost entirely free from the bisilicates. At one point near the south end of Young Loon lake a dike of dark-greenish compact material was seen cutting the granite and running N. 28° E. The contact between the mass of granitite and the sericitic schists exposed to the south on Hay lake and the Northeast arm of Lake Timagami crosses about half way over the portage between Commanda and Hay lakes.

Tétapaga creek, which enters the Northeast arm of Lake Timagami a little over two miles east of Broom island, serves to drain Tétapaga and Vermilion lakes, which, together with two small beaver-ponds and Kanichee-kinikisinik lake beyond, form a short and direct canoe-route to Net lake. From the east end of Tétapaga lake a portage runs to Turtle lake, which empties into a bay on the southwest side near the lower end of Net lake, and a short carry over some ledges of serisite-schist, from the south side of Turtle lake, affords an entrance to the Northeast arm of Lake Timagami to the north of Ferguson Mine point. Tétapaga creek, which runs in a southwesterly direction, is navigable for canoes for a distance of over a mile from the lake, and a portage of less than half a mile on the southeast side of the stream is all that intervenes before Tétapaga lake is reached. The rock exposed along the river is the dark greenish-grey and greenish hydromica and chloritic schists, striking from N. 50° E. to N. 60° E., and dipping to the northeast $< 60°$. These schists are interfoliated with occasional large oval patches or areas of a rusty weathering siliceous dolomite.

On Tétapaga lake the rock is, for the most part, a light greenish-grey sericite-schist, nearly vertical in attitude, and with a strike of N. 78° E. On Vermilion lake the rock is very similar in character, but has an average strike of N. 57° E., dipping to the southeast $< 80°$; while on the southeast shore a quartzose slate contains beds of red hematitic matter interlaminated with others of finely granular magnetite. In places the rock is associated with chlorite, and is greatly decomposed, showing large quantities of pyrite and pyrrhotite, the whole striking N. 70° E. and dipping southeast $< 75°$. On the portage running northwards from the beaver-pond that lies to the northeast of Vermilion lake the rock exposed is a light greenish-grey sericitic schist, striking from N. 44° E. to N. 59° E., and dipping southeast $< 70°$.

APPENDIX I.

LIST OF ELEVATIONS.

The following elevations were obtained from a careful compilation of the profiles of the Canadian Pacific railway, the Northern and Northwestern Division of the Grand Trunk railway, the location survey of the Nipissing and James Bay railway, together with a list published in 1860, by Thomas C. Clarke, C.E., in a report on the surveys of the Ottawa Ship canal. These were corrected by a comparison with the recently perfected levels of the United States Lakes Survey, as published by Mr. L. Y. Schermerhorn in the *American Journal of Science*, April, 1887.

The heights of the various lakes on the Mattawa river are from a list compiled by Mr. James White, Geographer to the Geological Survey of Canada.[*]

Elevations marked thus (*) have been deduced from actual levelling, while the others have been determined by means of the aneroid barometer checked at frequent intervals.

All heights are in feet above mean tide water at Quebec.

Miles from Montreal.	——	Height in Feet.
	1. Elevations on Canadian Pacific railway (Main line.)	
318	Mattawa	*564
324	Calvin	*696
330·1	Eau Claire	*591
336·9	Rutherglen	*837
343·9	Bonfield	*782
347·9	Nasbonsing	*785
357·5	Thorncliffe	*699
360	Nipissing Junction	*674·6
363·5	North Bay	*659
373·5	Beaucage	*673
378	Meadowside	*661
386·8	Sturgeon Falls	*685
389·7	Cache Bay	*652
397·4	Verner	*669
406	Warren	*689

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[*] See Trans. Roy. Soc. Can., 2nd Series, vol. 1., Sec. VI., pp. 188-189.

Miles from Junction.	—	Height in Feet.
	2. Elevations on the Canadian Pacific railway (Timiskaming branch.)	
	Junction with Main line	*571
11·25	Snake Creek siding	*543
24·30	Lumsden station and siding	*551
	Kipawa Junction	*580
37·95	Gordon Creek station	*593
38·67	Lumsden Mills siding	*801
	Bridge over Long lake	*831
	Bridge over "Y" lake	*861
45·77	Kipawa station and siding	*885
	Kipawa Lake dam	*883

Miles from Toronto.	—	Height in Feet.
	3. Elevations on Grand Trunk railway (N. & N. W. Division.)	
216·9	Crossing with the Nipissing and Nasbonsing railway	*743
219·6	Callander	*670
223·3	Nipissing Junction	*674·6

—	High Water.	Mean Level.	Low Water.
4. Elevations on Ottawa river.	feet.	feet.	feet.
Ottawa River junction with Mattawa river (1859.)	*509·5		*495·2
" " " (1890.)	*509		
" " " (1891.)	*506		
" " " (1892.)	*503		
" " " (1893.)	*507·5		
" foot of La Cave rapids	*509·5		*495·5
" head of La Cave rapids	*519		*505
" foot of Les Erables rapids	*520·31		*506·31
" head of Les Erables rapids	*532 63		*518·63
" foot of Mountain rapids	*533 13		*519·13
" head of Mountain rapids	*540·13		*522·23
" foot of Seven League lake	*540·13		*522·23
" head of Seven League lake	*542·63		*522·73
" foot of Long Sault rapids	*542·63		*522·73
" head of Long Sault rapids	*591·63		*577·63
" head of Long Sault rapids (1887)	*591		*572
" head of Long Sault rapids (1894)	*591		*571
Lake Timiskaming below Presqu'ile	*591		*577
" above Presqu'ile	*591		*577
" below Opimika narrows	*591		*577
" above Opimika narrows	*591·8		*577·8
" below Old Fort narrows	*591·8		*577·8
" above Old Fort narrows	*592		*578
Lac des Quinze		845	

Miles from Montreal.	——	High Water.	Low Water.
	5. Levels on Mattawa river	feet.	feet.
308·00	Mouth of Mattawa river	*509·5	*495·2
310·40	Foot of Plein Chant rapid and chute		*500·6
310·80	Head of Lac Plein Chant		*517·5
316·25	Foot of Des Epines rapids		*517·7
316·30	Head of Des Epines rapids		*523·3
316·85	Foot of Rapide de la Rose		*523·5
317·00	Head of Rapide de La Rose		*529·1
318·20	Foot of Rapide des Rochers		*530·5
318·30	Head of Rapide des Rochers		*535·3
319·00	Foot of Rapides des Aiguilles		*535·4
319·01	Head of Rapides des Aiguilles		*535·8
321·65	Foot of Chute de Paresseux		*535·8
321·85	Head of Chute de Paresseux		*569·6
322·20	Foot of Little Paresseux rapids		*569·6
322·35	Head of Little Paresseux rapids		*577·8
323·38	Foot of Lake Pimisi (Eel lake)		*590·6
324·53	Foot of Talon chute		*590·6
324·71	Head of Talon chute		*633·3
325·18	Rapid below Lake Talon		*633·3
325·33	Foot of Lake Talon	*639·3	*639·2
to 332·34	Head of Lake Talon		
336·08	Foot of Turtle lake	*665·9	*664·1
339·36 to 347·79	Trout lake	*667·8	*665
351·98	Lake Nipissing (East shore)	*647·8	*640·5

——	High Water	Mean Level.	Low Water.
6. Levels on Sturgeon river.	feet.	feet.	feet.
Lake Nipissing	*647·8		640·5
Sturgeon river, below Sturgeon Falls		645	
" above Sturgeon Falls		676	
" below Sandy falls		680	
" above Sandy falls		696	
" below Rapids		697	
" above Rapids		703	
" below Smoky falls		704	
" above Smoky falls	*732·14		*722·14
" mouth of Tomiko river	*736·51		*723·51
" mouth of Pike river	*740·60		*725
" mouth of Snake creek	*748		*730
" mouth of Timagami river	*752		*735
" at mouth of Maskinonge river	*795		*785
" at mouth of Wawashkashing creek		815	811
First lake (on Maskinonge river)		813	
Second lake		814	
Third lake (Murray lake)		815	
Fourth lake		826	
Maskinonge-wagaming lake		836	
Small lake (on Kookaganing creek)		844	
" " "		856	
" " "		864	

—	High Water.	Mean Level.	Low Water.
6. Levels on Sturgeon river—Cont.	feet.	feet.	feet.
Kookaganing lake		882	
McLaren river (at foot of portage from lake)		872	
Mattagomashing lake		871	
Small lake flowing into Wanapitei		859	
Wanapitei lake		858	
7. Levels on Timagami river.			
Mouth of Timagami river	*752		*735
Island lake		889	
Red Cedar lake		900	
Head of Swift Current		903	
Head of Sand-bar rapid		919	
Head of Burnt Portage rapid		930	
Head of rapid		936	
Head of Log-jam rapid		951	
Head of Twin rapids		957	
Head of Flat rapid		958	
Lake Cross		959	
Timagami lake		964	
8. Levels on Marten creek.			
Red Cedar lake		900	
Marten creek, above rapid		903	
" " Swift Current		904	
" " rapid		909	
" " Swift Current		909	
" " rapid		911	
" " "		914	
" " "		919	
" " "		920	
" " falls		935	
" " rapids		936	
Marten lake		936	
Small lake (on lot 6, con. v. Gladman)		990	
" (on lot 5, con. iv, Gladman)		990	
Wicksteed lake		941	
Forks of Boices and Mackenzie Lake outlets		944	
Boices lake		956	
Lower Red Water lake		1003	
Upper Red Water lake		1004	
Mackenzie lake		956	
Simpson lake		966	
Expectation lake		968	
Desperation lake		883	
Salvation lake		1008	
Breadalbane lake		986	
McDiarmid lake		992	
Fanny lake		994	
Bush lake		981	
9. Levels on Tomiko river.			
Mouth of the Tomiko river	*736·51		*723·51
Tomiko lake		795	

—	High Water.	Mean Level.	Low Water.
9. Levels on Tomiko river.—Cont.	feet.	feet.	feet.
Lake Chebogomog		798	
Cameron lake		803	
Tilden lake		928	
Lake lots 6 and 7, con. iii, Gladman		930	
Lake lot 7, cons. iii and iv, Gladman		932	
Kaotisinimigouang lake		948	
Poplar lake		949	
South Spruce lake		978	
North Spruce lake		978	
10. Levels on Ottertail river.			
Mouth of Ottertail river on Lake Timiskaming	*591·8		*577·8
White-beaver lake (Wabaunk lake)		841	
Ruth lake		991	
Beaver pond (head of river)		991	

—	Height.	High Water.	Mean Level.	Low Water.
11. Levels on Matabitchouan river.	feet.	feet.	feet.	feet.
Lake Timiskaming, at mouth of river		*591·8		*577·8
Summit of Matabitchouan portage	927			
Beaver mountain (King of Beavers)	1247			
First Bass lake			858	
Second Bass lake			858·5	
Third Bass lake			859	
Fourth Bass lake			864	
Rabbit lake			*938	
White-bear lake			*942	
Crooked or Snake Island lake			*953	
Net lake			965	
Thieving-bear lake			975	
Small lake			981	
Small pond			991	
Lake			1006	
Marshy stretch on river			1022	
Small pond			1027	
Mountain lake (head of Matabitchouan river)			1029	
Ferguson lake			971	
Duncan lake			971	
Petrout lake			996	
Lily lake			1001	
Peeshabo lake			1005	
Bogie lake			1007	
Granite lake			1006	
James lake			1023	
Waibikaiginaising or Rib lake			1013	
Cliff lake			1048	
Summit lake			1168	
Beaver meadow			1158	
Friday lake			1103	
Wilson lake			1173	

——	High Water.	Mean Level.	Low Water.
12. Levels on Macdonald creek.	feet.	feet.	feet.
Mouth of Creek on 4th Bass lake, Matabitchouan river		864	
Cooper or Macdonald lake		914	
Small lake		924	
Glasford lake		927	
Small lake		927	
Moxam lake		933·5	
Burwash lake		934	
Ross lake		936	
Rabbit lake, Southeast bay		*938	
13. Levels on the Montreal river.			
Mouth of Montreal river (Lake Timiskaming)	*591·8		*577·8
Farm house (Lumber depot) on Long portage, 860 feet			
Summit of Portage, 880 feet			
Montreal river at head of Long portage (3 miles fr. mouth)		736	
" above First rapid		748	
" " Second rapid		760	
" " Third rapid		770	
" foot of Fountain falls		773	
" head of Fountain falls		793	
" " Ragged chute		823	
" above Fourth rapid		830	
" " Fifth rapid		836	
" " Hound chute		861	
" at portage to Mud lake		869	
" at foot of Sixth rapid		871	
" at head of Sixth rapid		878	
" " Seventh rapid		882	
" at foot of Eighth rapid		883	
" at head of Eighth rapid		890	
" Bay lake		890	
" at mouth of Timagami branch		903	
Indian lake		901	
Round lake (Mountain lake)		911	
14. Levels on Route, Timagami to Red Cedar lake.			
Lake Timagami		964	
Olier lake		984	
Denedus lake		1022	
Wasacsinagama lake		1025	
Beaver meadow		1035	
Green lake		1046	
Brophy lake		1056	
Ingall lake		1050	
Jumping Caribou lake		1048	
Upper Twin lake		993	
Lower Twin lake		977	
Mann lake		975	
Norris lake		935	
Hanging-stone lake		918·9	
Red Cedar lake		900	
15. Levels of Various lakes.			
Pike lake (Lac aux Brochets) on Gordon creek			*794
Long lake, on Gordon creek			*820·5

—	High Water.	Mean Level.	Low Water.
15. Levels of Various lakes.—Cont.	feet.	feet,	feet.
"T" lake	*856	....	*849·5
Lake Kipawa	*880	....	*870·70
Summit of portage between Kipawa and Douglas	....	957	
Douglas lake	....	852	
Little Obashing lake	....	832	
Forest lake	....	862	
Birch lake	....	862	
Devil lake	....	834	
Bastien lake	....	877	
Thompson or McConnell lake	....	874	
David lake	....	869	
Obashing lake	....	822	
Summit of Road between Obashing lake and Ottawa river, 942 feet	....	....	
Small lake at head of Snake creek on old Winter road	....	847	
Second lake on Snake creek on old Winter road	....	827	
Long lake on White creek	....	852	
White lake at head of White creek	....	872	
White Beaver lake (East of McMartins point)	....	883	
First lake on Indian portage-route to Kipawa	....	883	
Emerald lake	....	1009	
Small lake at head of Opimika creek	....	1167	
Sharp lake	....	905	
Mud lake	....	900	
Bay lake	....	890	
Lady Evelyn lake	....	930	
Nonwakaming lake	....	955	
Big Whitefish lake	....	1010	
Lynx lake	....	1025	
Cole lake	....	1045	
Turner lake	....	1057	
Annima-Nipissing lake	....	1070	
Breeches lakes	....	1085	
Mannajigaina lake	....	1075	
Trout lake	....	857	
Wakmika lake	....	935	
Obabika lake	....	932	
Wawiagama lake	....	917	
Small lake south of Nonwakaming lake	....	961	
" between Nonwakaming and Wakmika lake	....	960	
Bear lake	....	997	
Angus lake	....	1051	
Free Portage lake	....	966	
Rankin lake	....	976	
Miller lake	....	977	
Kettle lake	....	1015	
Lake Nasbonsing	*781	*776	

APPENDIX II.

ON SOME CAMBRO-SILURIAN AND SILURIAN FOSSILS FROM LAKE TIMISKAMING, LAKE NIPISSING AND MATTAWA OUTLIERS.

By H. M. AMI.

LAKE TIMISKAMING.

CAMBRO-SILURIAN (ORDOVICIAN.)

In describing the Niagara formation on Lake Timiskaming Sir Wm. E. Logan remarks:—*"There are found lying on the Niagara limestone loose angular fragments of dolomite resembling that of the Birds Eye and Black River formation of Lacloche and Lake Nipissing, and holding *Strophomena alternata*, species of *Maclurea* like ***M. magna*, and *M*.** *atlantica*, *Orthoceras anceps*, and *O. proteiforme*." He adds:—'The source of these fragments has not yet been ascertained.'

From the assemblage of forms identified by the late E. Billings and recorded in Sir Wm. Logan's remarks above, there is no doubt that there must be represented somewhere in the vicinity of Lake Timiskaming one Cambro-Silurian horizon at least, i.e., the Birds Eye and Black River formation. It remains still to be ascertained whether any older members of the Cambro-Silurian occur under the somewhat extensively developed Silurian rocks. The Black River formation of the district is known so far only by loose, but angular and apparently not far-travelled pieces of limestone. It can scarcely be conjectured that these pieces of limestone came from any other district than the Timiskaming area, as there are no outcrops of rocks of Black River age known in the region to the north of Lake Timiskaming.

SILURIAN.

Silurian fossils abound on Lake Timiskaming and are well preserved in the several outliers. From the 'Head of Lake Timiskaming' the first collections were made by Sir Wm. E. Logan in 1845. These are recorded by Mr. E. Billings and enumerated on the page already referred to. The occurrence of *Halysites catenularia*, and of

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*Geology of Canada, (1863,) p. 335.

Favosites gothlandica, was sufficient evidence to enable Mr. Billings to definitely state that the rocks from which they came were Silurian. Some thirteen species were determined at the time.

Notes on certain species.

The collections made by Dr. Bell and Mr. Barlow are very extensive. One of the most prominent and characteristic features in the fauna represented is the prevalence of corals, not less than seventeen species of which have been recognized by Mr. Lambe. Of these corals, the 'chain-coral' (*Halysites catenularia*) and the 'honey-comb coral' (*Favosites gothlandica*) occur in great profusion. They are preserved for the most part in a silicified condition—not the best by any means for study—in a manner much resembling that in which the fossils of the Black River formation are found at Paquette rapids on the Ottawa river below Pembroke, Ontario.

Few of the higher forms of organisms characteristic of the Silurian period are found directly associated with the corals, but *Clathrodictyon vesiculosum,* Nicholson and Murie, one of the Hydromedusæ, does occur very abundantly and is associated intimately with the corals.

The Crinoidea are very rare; only three species having been recorded as yet from this basin.

The Annelids are represented by a single specimen of a Conodont, whilst the Bryozoa, so abundant in certain rocks of the Niagara and Clinton formations in the province of Ontario and in New York state, are rather sparsely distributed in the Lake Timiskaming rocks.

Brachiopoda occur in certain bands by themselves and at times are very abundant. Such is the case with *Atrypa reticularis,* Linnæus. *Pentamerus oblongus,* Sowerby, a form characteristic of the Wenlock in England and of the Niagara of the Interior Continental plateau of Palæozoic rocks in North America, occurs in vast numbers in a certain band of yellowish-grey limestone on Mann island.

The Lamellibranchiata or Pelecypoda are very rare, only two genera having been noticed from all the collections.

The Cephalopoda are well represented, and of these *Discosorus conoideus,* Hall, is the most conspicuous and interesting—although the Orthoceratites include amongst others:—*Actinoceras vertebratum,* Hall, (said to be identical with *Actinoceras backi,* Stokes, described from the Artic regions of North America) and several other forms peculiar to the Niagara formation of New York and Ontario.

The Trilobites are few. Two forms recorded may be the North

American representatives of the two European species *Calymene blumenbachii*, Brongniart; and *Encrinurus punctatus*, Wahlenberg. The Ostracoda are likewise very rare. A few fragments of Algæ occur in Mr. Barlow's collections and appear to represent two species previously recorded from rocks of similar age in New York state.

The whole fauna comprises eighty-eight species, representing fifty-nine genera. These species are for the most part forms referable to the Niagara formation, although a number of forms, such as the corals and brachiopods, are also well known to occur in rocks assigned to the horizon of the Clinton formation.

There are specimens of *Favosites gothlandica* from Mr. Barlow's collection of 1894 which measure a little more than fifteen inches in diameter or over four feet in circumference. The mode of growth of these Favosites is similar to that described by Prof. G. H. Girty in the case of *Favosites forbesi* var. *occidentalis*, and very perfect examples of such large dimensions are not rare on Mann island. They exceed in size and perfection of structure the large masses of Favosites from the Hamilton formation of Thedford, Ont. Large and small specimens of this species occur together, and such is the case also with specimens of the *Clathrodictyon vesiculosum*, Nicholson and Murie. This is the species which was described by Billings as *Stromatopora concentrica* of Goldfuss. The largest specimen met with measures fourteen, by ten, by eight inches.

Syringopora verticillata, Goldfuss, was described from specimens which came from Lake Huron. It is found in tolerable abundance in the Silurian of Lake Timiskaming. This fact, together with the occurrence of several other species which are common to the Silurian of Lake Huron in the Manitoulin island, in Michigan and Ontario, assist in confirming the view that the sea in which the Silurian deposits of the Lake Timiskaming basin were deposited was connected with the Silurian sea of the Lake Huron region.

Notes on Mr. Barlow's collections.

Chief island, Lake Timiskaming.—The fossils from this locality are poorly preserved, and occur in a rather coarse sandstone showing clear grains of quartz embedded in a light yellowish-grey dolomite. The beds from which they were obtained appear to form the basement or lowermost strata of the Silurian as developed at this point. The presence of *Halysites catenularia*, Linnæus, and of *Discosorus conoideus*, Hall, with other forms from this island, serve to indicate the presence of Silurian rocks on the southern side. These strata, which rest unconformably upon the denuded Archæan rocks whose surface is very irregular and uneven, must necessarily have contacts at various horizons or levels. It would not be at all surprising, indeed, to find arenaceous beds not only belonging to the Niagara formation and holding fossils representing different life-zones in this formation, but also similar beds holding older types of organisms, belonging to older formations in the lower levels of this old Palæozoic outlier or basin.

Mann island.—The bulk of the large collection obtained during the years 1893 and 1894 came from this locality. Forty-three species are represented. The rock in which they are preserved is a light-yellowish and fine-grained dolomite teeming with the remains of corals and hydroids. Certain bands, none calcareous, hold brachiopoda belonging to the species *Atrypa reticularis*, Linnæus. Several interesting and thin slabs of crinoidal limestone contain crinoid heads as well as stems. These are of special interest and deserve to be further studied. It is the only locality on the lake where tolerably perfect crinoid heads have been obtained, only imperfect fragments of columns or stems had been noticed previously.

Percy island.—From this place Mr. Barlow obtained only a few specimens from which nine species were recognized. Additional collections from this locality would probably reveal other forms of special interest. As already stated the occurrence of *Halysites catenularia* and *Discosorus conoideus* on this island is sufficient evidence upon which to refer the strata from which they came to the Silurian System.

The Fossil Corals.

In 1896 Mr. L. M. Lambe, of this Department, made a special study of the corals obtained, and he has prepared the following lists of species.—

Mann island, Lake Timiskaming, collected by A. E. Barlow.
1893-1894

Heliolites (Plasmopora) affinis, Billings.
Lyellia americana, Milne-Edwards and Haime.
Zaphrentis stokesi, Milne-Edwards and Haime.
Cyathophyllum articulatum, Wahlenberg.
Favosites gothlandica, Lamarck.
Alveolites niagarensis, Rominger (not Nicholson).
Limaria (Cœnites) crassa, Rominger.
Halysites catenularia, Linnæus.
Halysites compacta, Rominger.
Syringopora bifurcata, Lonsdale.
Syringopora verticillata, Goldfuss.

North End of Lake Timiskaming, collected by R. Bell, 1887.

Heliolites subtubulata, McCoy.
Zaphrentis stokesi, Milne-Edwards and Haime.
Strombodes pygmæus, Rominger.
Favosites gothlandica, Lamarck.
Cladopora cervicornis, Hall.
Alveolites niagarensis, Rominger (not Nicholson).
Alveolites seriatoporoides, Milne-Edwards and Haime.
Cœnites lunata? Nicholson.
Limaria (Cœnites) crassa, Rominger.
Halysites catenularia, Linnæus.
Halysites compacta, Rominger.
Syringapora Dalmanii, Billings.
Syringopora verticillata, Goldfuss.

The subjoined table enumerates the Silurian fossils found at the several localities in the northern part of Lake Timiskaming, the localities and collectors being as follows:—

1. Collection from 'Head of Lake Timiskaming' (*sic*) by Sir W. E. Logan, 1845.
2. From 'North End of Lake Timiskaming,' Dr. R. Bell, (*sic*) 1887.
3. Various collections by Mr. A. E. Barlow from Mann island in 1893 and 1894, also part of the 'Stewart Collection' from Mann island, obtained in 1892.
4. Percy island, Lake Timiskaming, A. E. Barlow, 1894.
5. Chief island, Lake Timiskaming, A. E. Barlow, 1894.

TABLE showing the genera and species of Silurian fossils from Lake Timiskaming.

—	1. Head of Lake Timiskaming.	2. North end, Lake Timiskaming.	3. Mann island.	4. Percy island.	5. Chief island.
PLANTAE.					
Bythotrephis gracilis (?), Hall	...	*	*	...	...
" *palmata*, Hall	...	...	*	...	...
HYDROMEDUSÆ.					
Clathrodictyon vesiculosum, Nicholson and Murie	*	*	*	*	...
CŒLENTERATA.					
Heliolites subtubulata, McCoy	...	*	...	...	...
" *(Plasmopora) affinis*, Billings	...	...	*	...	...
" sp., cf. H. niagarensis, Hall	...	...	*	...	...
Lyellia americana, Edwards and Haime	...	...	*	...	...
Zaphrentis stokesi, Edwards and Haime	...	*	*	...	...
" sp	...	...	...	...	*
Caninia or Streptelasma, sp	...	...	...	...	*
Cyathophyllum articulatum, Wahlenberg	...	...	*	...	...
" sp. indt	...	...	*	...	...
Strombodes pygmæus, Rominger	...	*	...	...	...
Favosites gothlandica, Lamarck	*	*	*	*	...
Cladopora cervicornis, Hall	...	*	...	...	...
Alveolites niagarensis, Rominger	...	...	*	...	...
" *seriatoporoides*, Edwards and Haime	...	*	...	...	...
Cœnites lunata (?), Nicholson	...	*	...	...	...
Limaria (Cœnites) crassa, Rominger	...	*	*	...	...
Halysites catenularia, Linnæus	...	*	*	*	...
" *compacta*, Rominger	...	*	*	...	...
Syringopora bifurcata, Lonsdale	...	...	*	...	...
" *verticillata*, Goldfuss	*	*	*	*	...
" *dalmanii*, Billings	*	*	*	...	...
ECHINODERMATA.					
Crinoidal fragments	*	*	*	*	...
Taxocrinus, n. sp	...	...	*	...	...
Dendrocrinus sp., cf. D. longidactylus, Hall	...	...	*	...	...
Thysanocrinus sp., cf. T. liliiformis, Hall	...	...	*	...	...
ANNELIDA.					
Arabellites, n. sp	...	*	...	...	...
BRYOZOA.					
Lichenalia concentrica, Hall	...	...	*	...	...
Phænopora expansa Hall	...	*	*	...	...
Trematopora, sp	...	...	*	...	...
Callopora sp., cf. C. *nummiformis*, Hall	...	*	...	...	...
Stictopora, sp	...	*	...	...	...

TABLE showing the genera and species of Silurian fossils from Lake Timiskaming—*Continued.*

—	1. Head of Lake Timiskaming.	2. Northend, Lake Timiskaming.	3. Mann island.	4. Percy island.	5. Chief island.
BRACHIOPODA.					
Orthis (Dalmanella) elegantula, Dalman	....	*	*		....
" *davidsoni*, de Verneuil.	....	*	*	....	....
Leptæna transversalis, Dalman	....	*	....	....	....
Leptæna rhomboidalis, Wilckens	....	....	*	*	....
Strophonella, sp	....	....	*	....	....
Strophemena, (?) sp., cf. *Leptæna corrugata*, Conrad	....	*	....	....	....
Chonetes (?), or *Strophomena (?)*	....	*	....	....	....
Platystrophia lynx, Eichwald	....	....	*	....	....
Leptocœlia hemispherica, Sowerby	....	....	....	*	....
Atrypa reticularis, Linnæus	*	*	*	*	....
" *nodostriata*, Hall.	....	*	....	....	....
" *intermedia*, Hall	....	....	*	....	....
Rhynchotrema cuneata, Dalman	....	*	....	....	....
Rhynchonella neglecta, Hall	....	*	....	....	....
" *interplicata*, Hall	....	*	....	....	....
" *acutiplicata*, Hall	....	....	....	....	....
" sp	....	....	....	....	*
Trematospira, sp., indt	....	....	*	....	....
Spirifer, sp., cf. *S. niagarensis*, Hall.	....	....	*	....	....
" sp., indt.	....	*	....	....	....
Meristella didyma, Dalman	....	*	....	....	....
" *naviformis* Hall	....	*	....	....	....
" sp.	....	....	....	*	....
Pentamerus oblongus, Sowerby	*	*	*	....	....
GASTEROPODA.					
Bucania stigmosa, Hall	....	*	....	....	....
Murchisonia subulata, Hall	....	....	*	....	....
" sp. No. 1	....	....	*	....	*
" sp. No. 2	....	....	....	....	*
Loxonema, n. sp.	....	....	*	....	....
" sp	....	*	....	....	....
Euomphalus, n. sp	....	....	....	....	....
Euomphalus alatus, Hisinger	....	....	*	....	....
Cyclonema cancellatum, Hall	....	*	....	....	....
Platyostoma, sp	....	*	....	....	....
LAMELLIBRANCHIATA.					
Modiolopsis, sp., cf. *M. erectus*, Hall	....	*	....	....	....
Pterinea, sp.	....	....	....	*	....
CEPHALOPODA.					
Discosorus conoideus, Hall	*	*	*	....	....
" *gracilis* (?), Foord	....	....	*	....	....
" sp. No. 1	....	*	*	*	....
" sp. No. 2	....	*	*	*	....

Table showing the genera and species of Silurian fossils from Lake Timiskaming—*Concluded.*

—	1. Head of Lake Timiskaming.	2. North end, Lake Timiskaming.	3. Mann island.	4. Percy island.	5. Chief island
CEPHALOPODA—*Continued.*					
Orthoceras, sp	....	....	•	....	....
" sp., cf. *O. claratum*, Hall	....	•	....	....	....
" sp., cf. *O. virgulatum*, Hall	....	....	•	....	....
" sp., cf., *O. cadmus*, Billings (?=*O. subcancellatum*, Hall)	....	....	•	....	....
Orthoceras rotulatum, Billings	•	....	....	....	....
Actinoceras vertebratum, Hall (?=*A. Baeki*, Stokes)	....	....	•	....	....
TRILOBITA.					
Calymene niagarensis, Hall (=*C. blumenbachii*, Brongniart)	....	•	....	....	....
Illænus, sp	....	•	....	....	....
Encrinurus, sp., cf. *E. punctatus*, Wahlenberg	....	•	....	....	....
Proetus, sp	....	•	....	....	....
OSTRACODA.					
Beyrichia, sp., cf. *B. lata*, Vanuxem	....	•	•	....	....
Isochilina, sp	....	•	....	....	....
Leperditia, sp	....	•	....	....	....

References.

1857. **Billings, E.**—'Report of Progress, Geol. Surv. Canada, for the years 1853-6.' Toronto, 1857. On p. 334 *Orthoceras rotulatum* is described from the head of Lake Timiskaming.

1858. **Billings, E.**—'Report of E. Billings, palæontologist, in Report of Progress, Geol. Surv. Canada, for the year 1857.' On pp. 147 and 171 Mr. Billings describes, and records the discovery of, *Syringopora dalmanii* and *S. verticillata,* Goldfuss.

1858. **Billings, E.**—'Canadian Fossils, containing descriptions of new Genera and Species from the Silurian and Devonian formations of Canada.' Extracted from Report of the Geol. Surv. Canada for 1857. Montreal, 1858, 31 pp.

1863. Billings, E.—'The Geology of Canada, from the commencement until 1863,' pp. 334-336 contains a chapter entitled: 'The Niagara Formation on Lake Timiskaming,' in which two lists of fossils prepared by Billings are given, p. 335.

1888. Foord, Arthur H.—'Catalogue of the Fossil Cephalopoda of the British Museum,' Part I., Nautiloidea, London, England, December, 1888:—in which *Actinoceras vertebrale* is recorded from Lake Timiskaming.

1896. Whiteaves, J. F.—'Canadian Stromatoporoids,' Can. Rec. Science, vol. V., No. 2, pp. 129-146, December, 1897, in which *Clathrodictyon vesiculosum,* Nicholson and Murie, is recorded from Lake Timiskaming.

1897. Ami, H. M.—'Notes on some of the Fossil Organic Remains from the Geological Formations and Outliers of the Ottawa Palæozoic basin.' Trans. Roy. Soc. Can., Sec. Series, vol. II., Sect. IV., 1896-1897, (Ottawa, 1897).

1899. Lambe, L. M.—'Canadian Palæozoic Corals,' Ottawa Naturalist, vol. XII., No. 11, pp. 219-220, February, 1899, where specimens identified with *Cyathophyllum articulatum,* Wahlenberg, are described from Mr. Barlow's collections on Lake Timiskaming.

THE MATTAWA OUTLIER.

In the autumn of 1894 Mr. A. E. Barlow submitted for examination a small but important collection of fossils from a locality on the north shore of the Ottawa river, six miles below Mattawa. The fauna represented in the pinkish-grey weathering and arenaceous limestones of this outcrop is that of the Black River and Trenton. The presence of *Receptaculites occidentalis,* Salter, *Orthis tricenaria,* Conrad, indicate an horizon at the close or summit of the Black River formation, whilst the occurrence of *Prasopora selwyni,* Nicholson, *Solenopora compacta,* Billings, *Rafinesquina alternata,* Emmons, and *Zygospira recurvirostra,* Hall, are eminently characteristic of the Trenton.

The occurence of this fauna at such a westerly point along the Ottawa valley and in such proximity to the Lake Nipissing outliers on the Manitou islands, together with the well-known occurrence of strata of the same age in the islands north of the Grand Manitoulin, serve to show that in Ordovician times the marine waters of the Lake Huron Palæozoic basin were directly connected with those of the Nipissing and Mattawa or Upper Ottawa regions. Every species recorded from this Mattawa outlier has been found in other deposits in the Ottawa valley, whilst most of them, if not all, are also recorded from the islands north of Lake Huron.

The following is a list of the species recognized in the collection from this outlier:—

PROTOZOA.

Receptaculites occidentalis, Salter.

ECHINODERMATA.

Crinoidal fragments, too imperfectly preserved for identification.
They resemble portions of stems of a species which may be referable to the genus *Glyptocrinus.*

BRYOZOA.

Prasopora selwyni, Nicholson. The microscopic sections prepared of this form exhibit no variation from typical specimens recorded from Peterborough, Ottawa, Montreal and other localities in Canada. This is no doubt the form which received the designations of *Favosites lycopodites, Chætetes lycoperdon,* and *Stenopora petropolitana* in the early reports of the New York and Canadian Surveys.
Frondose, and branching Monticuliporidæ.
Solenopora compacta, Billings. A form which may probably be referred to this species.

CŒLENTERATA.

Streptelasma corniculum, Hall.

BRACHIOPODA.

Strophomena incurvata, Shepard.
Rafinesquina alternata, Emmons.
Orthis, sp., cf. *O. tricenaria,* Conrad.
(Dinorthis) proavita, Winchell and Schubert.
Zygospira recurvirosta, Hall.

GASTEROPODA.

Lophospira bicincta, Hall. A young individual referable to this species.

TRILOBITA.

A fragment of a trilobite too imperfectly preserved for identification.

LAKE NIPISSING—THE MANITOU ISLANDS.

In 1854 Alexander Murray was the first to note the occurrence of flat-lying limestones on the Manitou islands of Lake Nipissing. In his Report for that year (p. 124) he refers the occurrence to the Black River formation. '*Ormoceras tenuifilum*,' or as this species is now called, *Actinoceras bigsbyi*, Stokes, is the characteristic form upon which the determination of the horizon was based.

In 1884 a further collection was made on these islands by Dr. A. R. C. Selwyn. This was subjected to a preliminary examination by the writer.

In 1896 a brief note was prepared for the Canadian Record of Science where seventeen species are enumerated.

In 1889 Mr. T. D. Ledyard, of Toronto, visited these islands and obtained an interesting collection, which was submitted to Mr. E. O. Ulrich for examination. The list of species prepared by the latter and embodied in a paper on the Black River limestone at Lake Nipissing by Prof. N. H. Winchell, in the American Geologist for September, 1896, contains besides other forms a number of Bryozoa not previously recognized from this locality.

In 1892 Rev. J. M. Goodwillie, M.A., of North Bay, made an excellent collection of the fossils, and communicated them to the Geological Survey Department at Ottawa. This collection was found to contain a number of forms hitherto unrecorded in other collections, and a preliminary study of its contents revealed many interesting species, all eminently characteristic of the Black River formation.

In 1894 Mr, A. E. Barlow collected along the west shore of the Great Manitou or Newman island, on the most southerly of the Manitou islands and on the west shore of McDonald island. From the first-mentioned of these collections by Mr. Barlow a Black River fauna was detected and *Columnaria halli*, Nicholson, *Stromatocerium rugosum*, Hall, *Lophospira helicteres*, Salter, and *Actinoceras bigsgyi*, Stokes, recorded, all of which are eminently characteristic. The presence of *Zygospira recurvirostra*, Hall, and of a form which is doubtfully referred to *Plectambonites sericea*, Sowerby, from the west shore of McDonald island, give a slight Trenton facies to the assemblage from this locality. It may be that further collecting will reveal a somewhat higher horizon than the zone of *Columnaria halli* usually indicates.

The following collections of fossils have been examined by the writer:—

Manitou islands, L. Nipissing, A. R. C. Selwyn, 1884.
Manitou islands, L. Nipissing, Rev. J. M. Goodwillie, M.A., 1892.

West Shore, Great Manitou islands, L. Nipissing, A. E. Barlow, 1894.

West Shore, McDonald island, L. Nipissing, A. E. Barlow, 1894.

Most southerly of Manitou islands, L. Nipissing, A. E. Barlow, 1894.

The subjoined list of genera and species includes all the forms recognized in these as well as in the other collections above mentioned.

PROTOZOA.

Stromatocerium rugosum, Hall.
Pasceolus globosus, Billings.

CŒLENTERATA.

Columnaria halli, Nicholson.
Tetradium fibratum, Safford.
Palæophyllum? sp.
Streptelasma corniculum, Hall.

ECHINODERMATA.

Crinoidal fragments, too imperfectly preserved for identification.
Sculptured plate of what appears to be a cystidean referable to the genus *Palæocysites*.

BRYOZOA.

Escharopora subrecta, Ulrich.
Escharopora limitaris, Ulrich.
Helopora mucronata, Ulrich.
Rhinidictya mutabilis, var. major, Ulrich.
Phyllodictya varia, Ulrich.
Batostoma winchelli, Ulrich.
Callopora multitabulata, Ulrich.
Several other Monticuliporoids referable to genera and species not yet examined microscopically, but which appear to belong to such genera as *Pachydictya, Amplexopora, Dekayia, Coscinium*, and *Monotrypella*.

BRACHIOPODA.

Strophomena incurvata, Shepard.
" *trentonensis*, Winchell and Schuchert.
Rafinesquina alternata, (Emmons).
Plectambonites sericea, Sowerby.
Orthis tricenaria, Conrad.
Rhynchotrema inæquivalvis, Castelneau.
Zygospira recurvirostra, Hall.

GASTEROPODA.

Eccyliomphalus trentonensis? Conrad.
Pleurotomaria (Clathrospira) subconica, Hall.
Murchisonia (Lophospira) helicteres, Salter.
" " *bicincta*, Hall.

GASTEROPODA—*Concluded.*

Maclurea? sp. indt.
Fusispira elongata, Emmons.
Trochonema umbilicatum, Hall.

LAMELLIBRANCHIATA.

Cyrodonta huronensis, Billings.
" *canadensis,* Billings.
" *subcarinata,* Billings.
Cyrtodonta sp. indt.
Ctenodonta levata, Hall.
Vanuxemia? sp. Hall.

CEPHALOPODA.

Vaginoceras multitubulatum, Hall.
Gonioceras anceps, Hall.
Actinoceras bigsbyi, Stokes.
Cameroceras proteiforme, Hall.
Nanno aulema, Clarke.
Orthoceras rapax, Billings or a very closely related species.
" *multicameratum,* Hall.
" *annellum,* Hall.
" *amplicameratum,* Hall.

TRILOBITA.

Asaphus, sp. Portion of the hypostome of a large individual of this genus possibly of *A. platycephalus* or *A. susae.*

OSTRACODA.

Leperditia fabulites, Conrad.
Aparchites neglectus, Ulrich.

References.

1857. MURRAY, ALEXANDER.—'Report of Progress Geol. Surv. Canada, for 1853-6, pp. 101-125, Toronto, 1857. On p. 124 there is reference made to 'fossiliferous rocks in the most western island of the Manitou group,' and *Ormoceras tenuifilum,* is recorded as evidence of the Black River age of the rocks in question.

1892. AMI, H. M.—'Palæontological Notes, No. 11. On the occurrence of Fossil Remains on the Manitou islands, Lake Nipissing, Ontario.' Can. Rec. Science, vol. V., No. 2, pp. 107-108, Montreal, 1892. Contains a review of Alex. Murray's paper (*loc. cit. supra.*) together with a list of fossils obtained by Dr. Selwyn in 1884, and referred to the Black River formation.

1896. ULRICH, E. O.—In Prof. U. H. Winchell's paper entitled: 'The Black River Limestone at Lake Nipissing.' American Geologist, vol. XVIII., No. 3, pp. 178-179, Minneapolis, Sept., 1896. A list of the species of fossils collected by T. D. Ledyard, Esq., of Toronto, in 1889, and determined by Prof. E. O. Ulrich, is embodied in this paper.

1898. WHITEAVES, J. F.—'On some Fossil Cephalopoda in the Museum of the Geological Survey of Canada, with descriptions of eight species that appear to be new. Ottawa Naturalist, vol. XII., No. 6, pp. 116-127, Ottawa 1898. On p. 116 Mr. Whiteaves records the occurrence of *Nauno aulema,* Clarke, from the collection made by Alexander Murray in 1854, from the Black River limestone at Western Manitou island (now called McDonald island), Lake Nipissing.

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Transcontinental location between Lake Nipigon and Sturgeon lake, Ont., by W. H. Collins.
Nanaimo and New Westminster districts, B.C., by O. E. LeRoy.

(B.—*Published by the Mines Branch.*)

On the location and examination of magnetic ore deposits by magnetometric measurements. Eugene Haanel. 1904.
Report of the Commission appointed to investigate the different electro-thermic processes for the smelting of iron ores and the making of steel in operation in Europe. (Only a few copies of this report are available.) By Eugene Haanel. 1904.
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Preliminary report on the industrial value of the Clays and Shales of Manitoba. (a few copies available.) J. W. Wells. 1905.

Mica, its occurrence, exploitation and uses. Fritz Cirkel. 1905. (Only a few c available.)

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Report of the Commission appointed to investigate the Zinc Resources of B Columbia and the conditions affecting their exploitation. W. R. In 1905.

Report on the present and prospective output of the Mines of the Silver-Cobalt of the Cobalt District. Eugene Haanel. 1907.

Report on the Mining Conditions of The Klondike, Yukon. Eugene Haanel. 19

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GEOLOGICAL SURVEY OF CANADA
A. P. LOW, DEPUTY HEAD AND DIRECTOR

REPRINT OF A REPORT
ON THE
ORIGIN, GEOLOGICAL RELATIONS AND COMPOSITION
OF THE
NICKEL AND COPPER DEPOSITS
OF THE
SUDBURY MINING DISTRICT
ONTARIO, CANADA

BY

ALFRED ERNEST BARLOW, M.A., D.Sc.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1907

No. 961

To A. P. Low, Esq.,
Director, Geological Survey of Canada.

Sir,—I beg to transmit, herewith, my revised report on the Origin, Geological Relations and Composition of the Nickel and Copper Deposits of Sudbury, Ontario, my original report of 1904 having run out of print. This report includes brief references to the character and extent of all the more important nickel deposits of the world, with a general statement of their production and methods of smelting and refining. Details of the mining, smelting and refining operations of the Sudbury ores are furnished, as well as complete statistical tables of production, prices, uses and composition of the nickel of commerce. It is believed that the report will serve to bring together in one volume all of the more valuable and critical original investigations in regard to these immense and apparently inexhaustible deposits.

Canada has realized the true importance and value of these mines and has, at last, taken her position, from which she will not recede, of being the largest producer of nickel in the world.

I have the honour to be, Sir,
Your obedient servant,
ALFRED ERNEST BARLOW.

Geological Survey Office,
Ottawa, January, 1907.

THE NICKEL AND COPPER DEPOSITS OF SUDBURY, ONTARIO.

BY

ALFRED ERNEST BARLOW, M.A.,D.Sc.

INTRODUCTION.

Fifteen years having elapsed since the appearance of the first official and detailed account of these famous ore bodies, (1) coupled with the fact of a renewed and even increased interest and activity in the mining of nickel, marked the time as most opportune when another attempt should be made to arrive at a more accurate and complete understanding of the true nature and extent of these deposits which have proved such a valuable asset to Canada. Besides, the first edition of the map of the Sudbury Mining district, published in 1891, to accompany a report by Dr. Robert Bell on the geology of this area (2), had nearly all been distributed, and this in spite of the fact that the Bureau of Mines of Ontario had on several occasions issued special editions of practically the same geological map to accompany the Annual Reports of their department, as, for instance, in the years 1892 and 1900. In addition it was felt that although the general accuracy and usefulness of this map had never been questioned it was lacking in certain details which are now known to be of the first importance, and which are most essential for a proper interpretation and judgment of these deposits. Thus, on the first map, the intrusive mass with which the Chicago and Victoria mines occur is entirely separated from a band of similar rock, along the southern borders of which the Gertrude, Creighton and North Star deposits are situated, whereas it has now been ascertained that all of these properties are developed along the southern boundary of one large and continuous band, constituting the southern or principal belt of the nickel bearing eruptive. Again, on this first map, no distinction is drawn between the masses or belts of nickel bearing norite, and certain older hornblende porphyrites, diorites and green schists, which, although closely related to, and often ressembling the norite, are altogether barren of deposits of the valuable sulphide material. This resemblance is particularly striking when, as is frequently the case, both have undergone more or less pronounced metamorphism. It is, therefore, not surprising that in the first instance they were confounded and mapped together. Moreover, the presence of the norite as a distinct geological unit was not suspected until long after this first work was completed, the associated greenstones being considered as portions of the norite which had been metamorphosed by the intrusion of the younger granite masses. Even the Bureau of Mines' map of 1902, which should have furnished the latest information in regard to this area, made no attempt whatever either to correct the more glaring inaccuracies in the geological boundaries, or to trace out the important line of separation between the nickel bearing eruptive proper and the closely related, though barren greenstones. .

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(1) Ann. Rep. Geol. Sur. Can., Vol. V., part S, 1890-91, pp. 122-138.
(2) Ann. Rep. Geol. Sur. Can, Vol. V., part F. 1890-91, pp. 1-95.

In undertaking this new work it was felt that by confining operations as closely as possible to the area characterized by the presence of the sulphide bearing norite and other kindred eruptives a more accurate knowledge would be obtained of the mineralogical composition, structure and age relations of the various rock masses, while at the same time the boundaries between the several formations could be drawn with a much greater degree of precision.

Two map sheets have been prepared to accompany this report, called respectively the 'Victoria Mines' and 'Sudbury' maps, each on a scale of one mile to an inch. The former covers an area of 220 and the latter 210 square miles, making a total of 430 square miles. The principal new work on the Victoria mines map has been the outlining of the two smaller bands of norite south of the Canadian Pacific railway. One of these, crossing the southeast corner of Drury, extends completely across the southern part of the township of Denison. This band, which comes to an end east of the Vermilion river, contains the Worthington, Mitchener and Totten mines. The first mentioned of these mines is famous as having produced the richest nickel ore in the district. On the other band, which forms the prominent ridge to the south of McCharles and Simon lakes on the Whitefish Indian reserve, no deposit of any economic importance has been found. The boundaries of the intrusive mass of younger granite which extends across the northern and central parts of Graham township, and thence into Snider and Waters townships, have also been outlined with considerable care. It is to be regretted that time did not permit the separation of the norite and the older greenstones and schists, but the geological work done in 1901 was intended to cover the whole of the southern belt in one season, and at the time it was considered more important to ascertain definitely the continuity or otherwise of the southern or main nickel range. The main mass of the norite, therefore, which runs northeast from the Victoria mines, was followed through the northern part of the township of Denison, and thence across the Vermilion river into the southern part of the township of Creighton, thus making connexion with the other mass of similar basic intrusive rocks which had been shown on geological maps previously issued. With the exception of a somewhat critical examination of some of the outcrops of the peculiar differentiation product, or 'micropegmatite' phase of the norite, exposed on the shores of Skill and Fairbank lakes, no new work has been done in the northwestern and western parts of this area, and the outlines of the formations are reproduced from the old geological map.

The geology of the region comprised in the Sudbury map sheet has all been revised, with special attention to tracing out the boundaries of the various masses of norite and separating this nickel bearing eruptive from the older greenstones. This map will serve to show in a very emphatic manner the intimate association of this peculiar eruptive, and the various nickel deposits, and the invariable development of the latter along the line of junction between this and the neighbouring rocks. In addition to these two map sheets, which exhibit on an adequate scale not only the general geological features, but also the relative position of all the more important mines, there are three other maps, each on a scale of 400 feet to an inch, which may be referred to as mining geological plans. These have been prepared with more care, and all details of topography, buildings, openings, &c., have been laid down as accurately as possible from surveys made by means of the transit and chain. They are expected to be of especial value to the individual companies whose properties they represent, but at the same time they will illustrate in detail many of the characteristic features of association, which most of these deposits possess in common with one another. The two sheets showing the district in the vicinity of the International Nickel Company's mines at Copper Cliff, and extending from Kelley lake on the south to the Lady Violet mine on the north, cover an area of about nine square miles. The third map sheet, which shows the geology in the neighbourhood of the Murray and Elsie mines, as well as the position of the various mining buildings, covers an area of nearly two square miles. The following bulletin is based mainly on the field work carried on during the seasons of 1901 and 1902. A short account of what was accomplished each year has already appeared in the Summary Reports of the Geological Survey Department.(1) In addition to this and other information which has appeared from time to time in the official publications of the Geological Survey Department and the Bureau of Mines of Ontario, certain details of original investigation, which throw much additional light on the origin and association of these deposits, have appeared in various scientific periodicals, many of which are not very easy of access to the ordinary reader. It has been the purpose of the writer, in the preparation of the following report, to bring together and make use of much of this widely scattered information, and by thus supplementing his own, render the present publication of wider application and greater service to the public.

in carrying out the field work the author was materially aided by Dr. Ludwig Mond, of London, England, under an agreement by which he was partially relieved from his duties on the Survey, during the six months from July 1 to December 31, 1901.

Much of the accuracy which the accompanying maps are believed to possess is due to the efforts of Mr. James White, Dominion Geographer, who kindly undertook the direction of the surveys necessary for a detailed mapping on a large scale of the area examined. This included in 1901 a traverse, by means of transit and steel band chain, of the main line of the Canadian Pacific Railway, from Wanapitei station to the northern boundary of the township of Dowling, a short distance northwest of Onaping station. The 'Sault' branch was similarly surveyed from Sudbury Junction as far west as Worthington station. Connexion was made with the observatory at Rayside, occupied by Astronomer O. J. Klotz. The position of this temporary observatory, in the township of Rayside, is stated by Mr. Klotz to be 606 feet west of the line between lots 2 and 3, in con. 1, and 441 feet north of the centre line of the Canadian Pacific railway. Its astronomical position, as determined by Mr. Klotz, is Long. 81°, 05′, 38″ W. and Lat. 46°, 32,′ 47″ N. This position was accepted and the projection of the map framed in accordance therewith. In 1902, Mr. White carried on similar detailed surveying necessary for the preparation of the two large scale map sheets of the area in the vicinity of the International Nickel Company's mines at Copper Cliff.

In the whole of this work the author had the advantage of the zealous and able assistance of Mr. O. E. Leroy, M. A. Sc., formerly Demonstrator in Geology at McGill University, Montreal, and this opportunity is taken to express his keen appreciation of Mr. Leroy's untiring efforts to promote, in every way, the objects of the work.

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(1) Sum. Rep. Geol. Sur. Can. (1901) pp. 141-145, (1902) pp. 252-267.

By kind permission of Dr. J. B. Porter, and with the approval of the University authorities, the magnetic separation of these ores was carried on in the mining laboratories of McGill University by Mr. W. M. Ogilvie, B.A. Sc.

Most of the assays and analyses are the work of Mr. Donald Locke, a graduate of the School of Mines, Freiberg, Germany, who for a short time was attached to this department as metallurgist and assayer.

The author desires to express thanks for information and assistance to Dr. Ludwig Mond, Dr. Bernhard Mohr and other officials of the Mond Nickel Company; to President A. P. Turner, Captain Lawson and other officers of the International Nickel Company, resident at Copper Cliff, Ont.; to the representatives of the Lake Superior Power Company, Great Lakes Copper Company and H. H. Vivian and Company, who were stationed in the district. It would be difficult to mention by name all those who, either with information or otherwise, have assisted in the object of these investigations, but the author would like in this connexion to express his deep gratitude to the residents of Sudbury, Copper Cliff and Victoria Mines, who showed him the greatest kindness and consideration during his sojourn in their midst.

PREVIOUS EXAMINATIONS AND DESCRIPTIONS.

The literature in regard to the nickel and copper deposits of the Sudbury mining district has already reached such large proportions that it seems advisable in passing to make brief mention of some of the principal publications which show evidence of original research, the results of which have added materially to our knowledge of the nature of the occurrences of these immense ore bodies. These deposits of pyrrhotite, with their unusually high content of nickel, and intimately associated chalcopyrite, are of importance, not only from the economic standpoint, but also from the point of view of science, as having furnished such strong presumptive evidence for regarding these, and similarly related deposits, as of igneous origin, and due to processes of differentiation in the original magma, from which they and the associated eruptive rocks have solidified.

The discovery of nickel at the Wallace mine in 1846,(1) although creating some excitement at the time, was soon forgotten, as well as the prediction which has since been amply verified, that deposits of both nickel and cobalt of economic importance would yet be located in this region. Attention was again drawn to the subject by the finding in 1856(¹) of nickel and copper on Salter's meridian line, a little over six miles north of Whitefish lake, and less than half a mile southwest of the main pit of the present celebrated Creighton mine, probably the largest deposit of nickeliferous pyrrhotite in the world. This was again lost sight of, or the discovery considered of no importance, perhaps because of the meagre information in regard to its occurrence, but more likely on account of the wild and inaccessible nature of the district in which the deposit had been found. The building of the Canadian Pacific railway quickly changed these conditions, and in less than ten years from the first opening of this means of access to the district all the mines which are at present working had been located.

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(1) Rep. of Progress, Geol. Sur. Can., 1848-49, pp. 61-63; Geol. of Can, p. 506.

The first statistics which were published concerning these deposits related to the export of copper ore in 1886, amounting to 3,307 tons, with a declared customs value of $16,404. (²) In 1887, this quantity had decreased to 567 tons, valued at $3,416. (³) The discovery of nickel in the ore about this time decided the Canadian Copper Company to install the necessary plant for the production of nickel and copper matte, and in the preparation for this and other mining development work no exports are recorded from this district in 1888.

In October, 1887, Mr. J. H. Collins visited the Sudbury region to examine into the extent and economic possibilities of the so-called copper mines. On June 6th, 1888, he read a paper before the Geological Society of London, 'On the Sudbury Copper Deposits,' in which he embodied the results of these examinations, which, however, seem to have been restricted mainly to the area in the immediate vicinity of the Copper Cliff and Stobie mines. An abstract of this paper was afterwards published, (⁴) accompanied by two cross sections of the mines above mentioned, showing the geological association and position of these deposits. The author considers the main ore bodies to have been the result of secondary action, the sulphides occupying fissures along certain lines of weakness, produced by the intrusion of igneous material. In the discussion that followed Mr. Attwood stated his conviction that the diorites had brought up the metals. At the end of the paper a note is added bearing the date of October 22nd, 1888, that the ore of the Evans mine contains Copper, 3 per cent; Nickel, 3·5 per cent; Iron, 40 per cent; Sulphur, 24 per cent; Rock, 29·5 per cent.

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(1) Rep. of Progress, Geol. Sur. Can. 1853-56, pp. 180-181.
(2) Ann. Rep. Geo. Sur. Can., 1886, Part S, p. 25.
(3) Ann. Rep. Geo. Sur. Can., 1887-88, Part S, p. 21
(4) Quart. Jour. Geol. Soc. Lon., Vol. XLIV., 1888 pp. 84-838.

In October, 1888, Mr. Francis L. Sperry, then chemist to the Canadian Copper Company, sent a small quantity of what seemed a remarkable mineral to Professor H. L. Wells, of the Sheffield Scientific School at New Haven, Conn. A few tests sufficed to show that the substance was essentially an arsenide of platinum. Several ounces of this mineral had been obtained in milling certain loose material (gossan), associated with the sulphides at the Vermilion mine in the township of Denison. A complete statement of facts relative to its composition, physical characters and crystallographic behaviour, was prepared by Profs. Wells and Penfield, who proposed the name 'sperrylite' for this new mineral in honour of its discoverer. (1)

About the same time Profs. Clarke and Catlett (2) of Washington obtained through two different channels certain samples of nickel ores taken from the Vermilion mine, belonging to the Canadian Copper Company. From one source they obtained two masses of sulphides to be examined for nickel and copper, from the other came similar sulphides, together with a series of soil and gravel-like material (gossan), seven samples in all. In the latter case an examination for platinum was requested, and in five of the samples above mentioned it was found the gravel yielded 74·85 ozs. of metals of the platinum group to the ton of 2,000 pounds. The sulphide ores were all of a similar character. They consisted of mixed masses, in which a grey, readily tarnishing substance was predominant, with some chalcopyrite, possibly some pyrite, and a very little quartz. An analysis of carefully selected material of the nickel mineral showed its formula to conform in general with that of polydymite, which had previously been described by Laspeyres from Grünau, Westphalia, of which it is evidently a ferriferous variety.

At the Buffalo meeting of the American Institute of Mining Engineers, W. H. Merritt, Toronto, contributed a paper on 'The Minerals of Ontario and their Development,' in which he includes a brief description of the Sudbury deposits.(3)

In the Summary Report of the Geological Survey for 1888 Dr. Bell (4) mentions that 'the modes of occurrence and the geological relations of the economic minerals of the districts examined (between Lake Huron and Montreal river) were carefully studied. The metals which give most promise are the copper and nickel deposits which have been worked for the last three years near Sudbury.' Again, in the report for 1889, Dr. Bell, (1) after a brief sketch of the geology of the area included in the Sudbury map sheet, gives a few notes on the character and mode of occurrence of these deposits, as also the progress of the mining and metallurgy which were then in vigorous operation. He viewed the pyrrhotite as a true nickeliferous variety, in which some of the iron is replaced by nickel. The deposits are described as 'stock-works' in which the vein structure is very obscure. The ore bodies are regarded as usually occurring in some form of diorite, the concentration of the ore being perhaps connected in some way with certain diabase dikes which were in some cases seen near the deposits.

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(1) Amer. Jour. Sc., Vol. XXXVII., 1889, pp. 67-73; also Zeit. für Kryst. Vol. XV., pp. 285 and 290-291.

(2) Amer. Jour. Sc. Vol. XXXVII., 1889, pp. 372-374.

(3) Trans. Amer. Inst. Min. Eng. Vol., XVII., 1888-89, pp. 293-300.

(4) Ann. Rep. Geol. Sur. Can., 1887-8, p. 79 A.

At the Ottawa meeting of the American Institute of Mining Engineers, held in October, 1889, Dr. E. D. Peters, who had charge of the operations at the Canadian Copper Company's mines near Sudbury, read a paper 'On the Sudbury Ore Deposits.' (2) He opens with a short and very general statement of the geological conditions, makes a passing mention of the two principal sulphides which constitute these deposits, and devotes the rest of his paper to a description of the equipment and methods of mining and metallurgy pursued by the company of which he was the manager.

In 1890, as one of the Royal Commissioners to inquire into the mineral resources of Ontario, Dr. Robert Bell, of the Geological Survey of Canada, in treating of the 'Geology of Ontario with Special Reference to Economic Minerals,' devotes some attention to the nickel and copper deposits of the area in the vicinity of Sudbury. (3)

In 1891 (4) Dr. Bell described in greater detail the nature and extent of these deposits and also their geological relations, giving the results of the field work of the Geological Survey in this area during the three years 1888-900. Accompanying the same volume the first geological map of the district appeared, showing in this graphic way the limits of the different formations or subdivisions of these old rocks, over an area of 3,456 square miles. This map, although faulty and inaccurate in places, has been the basis of all subsequent geological work undertaken in this district, although it is now superseded in certain areas by the maps lately published by the Bureau of Mines of Ontario, and those issued to accompany the present bulletin. The imperfections of these latest maps will also in turn become apparent as the region is cleared and opened up and more detailed information in regard to the distribution of the various rock masses is thus possible.

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(1) Ann. Rep. Geol. Sur. Can., 1888-89, pp. 29-32 A.

(2) Trans. Am. Inst. Min. Eng., Vol. XVIII. (1889), pp. 278-289.

(3) Min. Res. of Ont. 1890, p. 24; also pp. 434-435; also Ann. Rep. Bur. of Mines, Ont. 1891, pp. 88-90.

(4) Ann. Rep. Geol. Sur. Can., Vol. V., Part F., pp. 1-95; also Bull. Geo. Soc. Am., Vol. II., 1891, pp. 125-137.

On March 6th, 1891, (1) the author of the present bulletin read a paper before the Logan Club of Ottawa 'On the Nickel and Copper Deposits of Sudbury,' which was published in June of the same year, in which appears a very definite statement affirming an igneous origin (2) for these masses of sulphide material, in the following words:—

'The ores and the associated diabase were, therefore, in all probability simultaneously introduced in a molten condition, the particles of pyritous matter aggregating themselves together in obedience to the law of mutual attraction.' In the same paper the author makes the following significant statement, which has since been proved by means of the magnetic separation of the ore:— 'The nickel is usually spoken of as replacing an equal quantity of iron in the pyrrhotite, but the discovery of undoubted crystals of millerite or sulphide of nickel, 150 feet below the surface at Copper Cliff mine, as well as the more recent recognition of polydymite, a ferriferous sulphide of nickel, at the Vermilion mine, in the township of Denison, seem to justify the assumption, that in the more highly nickeliferous deposits of the region at least, the nickel is also present as a sulphide, disseminated through the ore masses like the iron and copper.' In 1891 Mr. T. L. Walker, then chemist at the Murray mine, obtained 30 per cent of nickel in some bright cleavable fragments of a mineral which occurred in the form of more or less rounded patches in the ordinary nickeliferous pyrrhotite at the Worthington mine. The writer, who had provided Mr. Walker with these samples, suggested the advisability of a complete analysis of as pure material as could be selected. It is to be regretted for Walker's sake, so far as priority in the first recognition of pentlandite in this district is concerned, that the present writer, in publishing the results of this first analysis, (3) merely stated his own belief that these peculiar nodular masses probably represented a mixture in which millerite was the most prominent constituent, omitting to make mention of the fact that the chemist had stated his belief that the material was almost pure 'Eisennickelkies,' the German synomym for pentlandite. At this time it was considered of more importance to emphasize the fact, which had grown beyond a conviction, that the nickel was undoubtedly present in these ore bodies as a distinct sulphide, mechanically intermixed and probably separable, and not as replacing a portion of the iron in the pyrrhotite. It was even considered probable that several nickel sulphides, and not one alone, contributed to the unusual enrichment of these ores.

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(1) Ottawa Naturalist, June, 191,, pp. 1-20; also Ann. Rep. Geol. Sur. Can., Vol. V., Part S., 1890-91, pp. 122-138.

(2) See also a paper by Dr. Robert Bell on 'The Nickel and Copper Deposits of Sudbury district, Canada.' Bull. Geol. Socy. of Am., Vol. II., 1891, pages 135-36.

(3) Ann. Rep. Geol. Sur. Can., 1890-91, Part SS., pp. 116-117.

The report of the Division of Mineral Statistics and Mines of the Geological Survey for 1890, although not published until the following year, contained the first statistics showing the production and export of nickel and copper matte from the Sudbury district. This was likewise accompanied by a somewhat detailed description of the deposits, to which attention has already been drawn. (1) Previous to this, however, in the report (2) of the same department for 1889, mention is made of the production of nickel in Canada, but the figures of production then supplied were only used in the summary of production. This course was necessary at the time, as the figures then available represented the production of only one company, who gave the figures on the understanding that they were only to be used in the compilation of totals.

In the first report of the Ontario Bureau of Mines for 1891, then just organized, considerable space is devoted not only to the statistics of production of nickel and copper matte, but also to various details regarding the geological relationship of the ores, the methods of mining and metallurgy, as well as the use and value of nickel. It also contains the first of the annual reports of the inspector of mines, which each year since has contained an epitomized statement of the progress of mining and smelting in this area.

In 1891, Mons. J. Garnier, (3) who had become famous as the discoverer of the New Caledonia nickel deposits, visited Canada, and on his return to Paris furnished an account of his examination in a paper entitled, 'Mines de Nickel, Cuivre et Platine du District de Sudbury, Canada.'

In 1892, Dr. S. H. Emmons, of Youngwood, Penn., and President of the Emmons Metal Company, announced the discovery of three new nickel minerals from the Sudbury district, for which he proposed the names Folgerite, Blueite and Whartonite. (4) The substances thus named were stated to be sulphides of iron and nickel, the proportion of the latter metal varying from 3·76 per cent in blueite to 35·20 per cent in folgerite. All authorities, however, agreed that none of these are definite mineral species, being mixtures of different sulphides. Thus folgerite is regarded as impure pentlandite, blueite is a nickeliferous pyrite, and whartonite a mixture. A perusal of Dr. Emmons' methods of analysis, and the variability of his results are sufficient proofs that none of these names which he proposes should receive a place in mineralogical literature. About the same time Dr. Emmons conducted some rather crude and evidently hurried experiments in regard to the separation of the components of the pyrrhotite by means of magnetism, but the results are far from satisfactory. (1) The material on which the trials were made came from both the Gap mine, Pa., and Sudbury, Ont.

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(1) Ann. Rep. Geol. Surv. Can., 1890-91, Part S., pp. 121-143.

(2) Ann. Rep. Geol. Surv. Can., 1888-89, Part S., 1889, pp. 5 and 123.

(3) Mem. Soc. des Ing. Civils, Paris, 1891.

(4) Jour. Am. Chem. Soc., Vol. XIV., No. 7; also Ann. Rep. Bur. of Mines, Ont. 1892, pp. 167-170

In 1892, Mons. David Levat, formerly Director-General of the Société de Nickel, prepared a memoir on the production and uses of nickel and its alloys, entitled 'Progrès de la Métallurgie du Nickel,' (2) an abstract from which is translated and printed in the report of the Bureau of Mines of Ontario. (3) Besides a description of the metallurgical treatment of the Sudbury ores he institutes a comparison between these and the New Caledonia ores, giving all necessary details in regard to these latter, their composition, metallurgy, transportation, mining operations, and concludes with certain particulars relating to the composition of the nickel of commerce, its alloys, and statistics of production.

During the summer of 1890 the late Baron von Foullon, of the Geological Survey of Austria, spent a few weeks in the district, directing his attention chiefly to the determination of the relative ages of the different rocks. His collection of rocks for future study contained a specimen obtained from one of the detached blocks of material which had been blasted out to make room for the foundations of the smelter at the Murray mines. Examination of thin sections of this specimen under the microscope revealed for the first time the identity of what was evidently a typical and unaltered representative of the nickel bearing eruptive, showing it to contain, besides the plagioclase, strongly pleochroic hypidimorphic individuals of hypersthene, together with a smaller amount of diallage, both of these last mentioned minerals being often bordered with hornblende. The rock thus evidently belonged to the general type of gabbros, which by the abundance of the hypersthene is related to the norites. (1) This was the first recognition of the true character of the eruptive with which the nickel deposits are so intimately associated, although the late Professor G. H. Williams had in 1901 described (2) a very similar rock from the vicinity of the Blezard mine, but which in the description of the field relations furnished him, had been reported as occurring in a later dike. In 1893, Dr. A. P. Coleman (3) showed that the country rock of the nickel deposits south of Clear lake, on the Northern Nickel range, was a gabbro containing both diallage and enstatite. In the same publication he gives a description of the petrographical characters of the peculiar type of rock to which Williams first gave the name 'micropegmatite,' and which occurs here as elsewhere, throughout the district, in intimate association with the sulphite bearing eruptive.

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(1) Jour. Am. Chem. Soc., Vol. XIV., No. 10; also Ann. Rep. Bur. of Mines, Ont., 1892, pp. 163-166.

(2) Ann. des Mines, Paris, 1892, pp. 141-224.

(3) Ann. Rep. Bur. of Mines, Ont., 1892, pp. 149-162.

In 1893, Prof. S. L. Penfield recognized and described for the first time the mineral pentlandite, from the Sudbury district, found in some sulphide material sent to him some years previously by Mr. F. L. Sperry. (4) Immediately following this article, in the same publiaction, he criticises rather severely the methods of analysis adopted by Dr. Emmons in his attempt to establish the claims of folgerite, blueite and whartonite to be recognized as new mineral species.(5)

In the same year, David H. Browne, (6) chemist of the Canadian Copper Company, challenged the accuracy of Dr. Emmon's magnetic work, as also the conclusions based thereon, so far at least as the material from Sudbury is concerned. At the same time he published the details of certain personal experiments in connexion with the magnetic separation of the ores from the Copper Cliff, Evans and Stobie mines. The ore was first handpicked and then crushed to various degrees of fineness. By means of these trials he succeeded in dividing the material thus prepared into a magnetic and non-magnetic product, the analysis of the latter showing a close resemblance to the pentlandite described by Penfield.

In June, 1893, T. L. Walker (7) visited the Vermilion mine and procured some additional material similar to that in which Wells and

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(1) "Ueber einige Nickelrzvorkommen," Jahr. d. k-k. geol. Reichsanstadt, Vol. XLII., pp. 223-310, Vienne, 1892.

(2) Ann. Rep. Geol. Surv. Can., 1890-91, Part F, p. 77.

(3) 'The Rocks of Clear lake near Sudbury,' Can. Rec. Sc., Vol. V., 1892-93, pp. 343-346.

(4) Am. Jour. Sc., Vol. XLV., 1893, pp. 493-494.

(5) Am. Jour. Sc., Vol. XLV., 1893, pp. 494-497.

(6) Eng. and Min. Jour. Dec. 2nd, 1893, Vol. LVI., pp. 565-566.

(7) Am. Jour. Sc., Vol. I., 1896, pp. 110-112.

Penfield had first discovered sperrylite. The evidence of these new specimens of this comparatively rare mineral enabled him to publish further details in regard to its crystallographic behaviour. After critical examination of the associated sulphides he concludes that this sperrylite is associated with the chalcopyrite, and not with the pyrrhotite, and that accordingly nickel mattes from mines low in copper contain very little platinum, while those richer in copper afford a matte proportionately richer in platinum. He mentions the fact, however, that the polydymite of Clarke and Catlett contains from 0·006 per cent to 0·024 per cent of platinum. (1)

In April, 1893, Prof. W. L. Goodwin (2) announced the discovery of a highly nickeliferous pyrite, occurring at the Murray mine, and published an analysis of this somewhat unusual association. The material, however, on which the examination was conducted, was massive and somewhat decomposed. A little later, however, T. L. Walker secured several specimens showing druses of small bright cubic crystals. These were found associated with marcasite, (containing no nickel or cobalt) magnetite, galena, chalcopyrite and nickeliferous pyrrhotite. An analysis of this new and fresh material was made, and the conclusion reached that the specimens represented true nickeliferous pyrite, in which the isomorphous elements, iron and nickel, replaced each other in varying proportions. (3)

During the summer and fall of 1893, E. Renshaw Bush, while pursuing professional work, visited some of the more important deposits, afterwards publishing his observations in a paper called 'The Sudbury Nickel region.' (4)

On December 4th, 1893, Philip Argall, of Denver, Col., presented a paper to the Colorado Scientific Society on 'Nickel, the Occurrence, Geological Distribution and Genesis of its Ore Deposits.' This author gives a short but rather complete statement of the character, composition and distribution of the three groups of the ores of nickel —arsenides, sulphides and silicates—and makes special mention of the main features and importance of the Sudbury ore deposits. (5)

On January 12th, 1894, Dr. Frank D. Adams, of Montreal, submitted a paper to the General Mining Association of the Province of Quebec, 'On the Igneous Origin of certain Ore Deposits.' In this paper he gives a synposis of the main conclusions reached by Prof. J. H. L. Vogt, of Christiania, from his examinations and study of the nickeliferous sulphides of Norway, and agreeably with these Dr. Adams claims an igneous origin for the various Sudbury occurrences, the concentration of the ore being the direct result of magmatic differentiation of the peculiar type of eruptive with which the deposits of both countries are always associated. (1)

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(1) Bull. U. S. G. S., No. 64, p. 21.

(2) Can. Rec. Sc., Vol. V., 1892-93, pp. 346-347.

(3) Am. Jour. Sc., XLVII., April, 1904, pp. 312-314.

(4) Eng. and Min. Jour., March 17, 1894, Vol. LVII., pp. 245-246.

(5) Proc. Col. Sc. Soc., Vol. IV., 1891-93, pp. 395-421.

In 1895, Prof. J. F. Kemp, of Columbia University, New York, gives 'An Outline of the Views held To-day on the Origin of Ores,' offering an explanation based on the laws of thermo-chemistry, to explain the concentration of these sulphides of iron, copper and nickel. (2)

In 1897, Dr. T. L. Walker presented his inaugural dissertation, to obtain the degree of Doctor of Philosophy, to the University of Leipzig, taking as his subject 'Geological and Petrographical Studies of the Sudbury Nickel district, Canada.' This thesis was afterwards communicated to the Geological Society of London by Prof. J. J. H. Teall, and subsequently published in an abridged form. (3) This publication contains an epitome of Dr. Walker's studies of the rocks which are most intimately associated with the nickel deposits. The author is in full agreement with Vogt, Adams and others, regarding these ore bodies as of igneous origin, owing their present position and dimensions to magmatic differentiation. He furnishes very complete details of the petrographical character, not only of the nickel bearing eruptive, but also of the associated greenstones and the clastic rocks of the Huronian, making brief mention of the mineralogical composition of the Laurentian gneisses exposed near Wanapitei station. Dr. Walker was the first to recognize that the 'micropegmatite,' classed on previous geological maps as belonging to the Laurentian, which it resembles, is really a differentiation phase of the prevailing norite. The later dikes of olivine diabase are also described in considerable detail. The whole publication may be characterized, in brief, as the most complete statement in regard to the geology and petrography of the district, which had yet appeared.

In 1900, J. Watson Bain prepared 'A Sketch of the Nickel Industry,' which treats of the source and production of nickel ores, the metallurgy of both the New Caledonia and Sudbury products, concluding with a brief statement of the composition and uses of nickel.(1)

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(1) Can. Min. Review, February, 1894.

(2) Min. Industry, Vol. IV., 1895, pp. 755-766.

(3) Quart. Jour. Geol. Soc. Lon., Vol. LVIII., (1897), pp. 40-66.

In 1901, Dr. A. P. Coleman gives certain petrographical details of the nickel bearing eruptive and the associated greenstones, with special reference to occurrences of these rocks between the Stobie and Nickel Mountain mines. He also furnishes an account of the mineralogical composition and character, as revealed by the microscope, of some of the sedimentary rocks classified as Huronian in this district.(2)

In 1901, (3) and again in 1902, (4) the writer gives certain preliminary information in regard to the geology and petrography of the Sudbury district.

In the summer of 1902, Profs. Victor Goldschmidt and William Nicol prepared a very complete statement of the crystallography of sperrylite, the material being obtained from the original locality at the Vermilion mine.(5)

In 1902, C. W. Dickson, (1851 Exhibition Scholar from Queen's University, Kingston, and doing post-graduate work at the School of Mines, Columbia University, New York) succeeded in separating sperrylite from the unaltered chalcopyrite obtained at the Victoria mines, and thus proved definitely that the platinum was associated with the copper sulphide. (6) This is in agreement with the results obtained by Walker, some years previously, to which reference has already been made, and also accords with the views of Prof. Vogt, from analyses of the various ores from the Norwegian nickeliferous pyrrhotite deposits.(7)

At the meeting of the American Institute of Mining Engineers, held in Albany in February, 1903, Mr. Chas. W. Dickson, to whom reference has already been made, submitted a paper entitled 'The Ore Deposits of Sudbury, Ontario.' The information thus published was also presented in the form of a thesis, to obtain the degree of Ph. D. at Columbia University, New York city. (8)

This publication marks a decidedly new departure, not only in the methods of research adopted, but also in the results sought to be obtained, and if the conclusions reached seem new and startling, and at variance with many of the preconceived notions entertained in regard to the composition and origin of these ore bodies, the author must be given the credit for having weighed all the evidence and exhausted every means to prove the validity of his conclusions.

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(1) Ann. Rep. Bur. of Mines, Ont., 1900, pp. 213-224.

(2) Ann. Rep. Bur. of Mines, Ont., 1901, pp. 206-208.

(3) Sum. Rep. Geol. Surv. Can., 1901, pp. 141-145.

(4) Sum. Rep. Geol. Surv. Can., 1902, pp. 252-267.

(5) Amer. Jour. Sc., Vol. XV., 1903, pp. 450-458.

(6) Amer. Jour. Sc., Vol. XV., 1903, pp. 137-139.

(7) Zeit für Prak. Geol., Aug., 1903, pp. 258-260.

(8) Trans. Am. Inst. Min. Eng. (Albany Meeting) February, 1903, 65 pp.

Mr. Dickson mentions that one of the purposes of his investigation has been to ascertain whether the nickel and cobalt replace the iron isomorphously in the Sudbury pyrrhotite. Another purpose has been to try to find a definite formula for the sulphide of this district, with the idea of comparing it with similar minerals from other localities. The thesis is divided into two main portions, as follows:—I. The relation of nickel to pyrrhotite, and II. Genesis of the Sudbury ores.

The former of these two parts of Mr. Dickson's paper deals, in the first place, with a general statement of the Sudbury nickel region. This is followed by a summary of the composition and origin of pyrrhotite, to which is added a table, showing the percentage of nickel and cobalt in this mineral. Then succeeds a brief description of the Sudbury pyrrhotites, with tables indicating the percentage of nickel, cobalt and copper, not only in the ore of the principal mines, but also the average composition of some of the resulting mattes.

Mr. Dickson then discusses the methods pursued, and the results of his investigation into the magnetic separation of the pyrrhotite, and as a result of these experiments he concludes that all of the nickel, in the Sudbury ores at least, occurs as a separate mineral, and that in this district there does not exist a true nickeliferous pyrrhotite, in the sense that the nickel isomorphously replaces part of the iron in that mineral. In the second part of the paper he adduces strong evidence in support of his opinion that all of the Sudbury ore deposits are of essentially and predominantly secondary origin. The evidence adduced is derived not only from a study of the larger field occurrences of the deposits and associated rocks, but also finds abundant support in the relations between the ores and rock minerals, as seen under the microscope.

A comparison is made of these Sudbury deposits with those of Rossland, B.C., and Ducktown, Tenn., which are stated to show many remarkable and essential points of similarity, and concerning whose secondary origin there can be no doubt.

In 1903, Dr. A. P. Coleman published his account of 'The Sudbury Nickel Deposits,' (1) giving the results of the field operations undertaken at the instance of the Bureau of Mines of Ontario, in the summer of 1902. This is, doubtless, the most comprehensive and satisfactory description of these deposits which has yet appeared.

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, pp. 235-290.

The work is copiously illustrated with photographs of the different mines and buildings, together with several small maps showing the progress of the surface work, and the disposition of the various openings and mining buildings. It is also accompanied by two coloured geological maps, representative of the area in the vicinity of Copper Cliff and Stobie mines. It is not considered necessary in this connexion to summarize the results of this work, as the publication is of such recent date, and readily available to any one who desires to take advantage of this information; and no one interested in the geological and petrographical problems involved should be without it. In 1903, Dr. Coleman continued this work, directing his attention to the mapping out in detail of the outline of the Northern nickel range, in order to determine its connexion or otherwise with the Southern or Main range.

It is proposed, that, during the coming season, Dr. Coleman will again continue this work, with the intention of ultimately publishing a monograph, which will contain, in succinct form, all essential information in regard to these deposits which have figured so largely in the mining industrial development of Canada.

HISTORY OF DEVELOPMENT.

The presence of large deposits of nickel and copper in the vicinity of the town of Sudbury, and close to the boundary between the Districts of Algoma and Nipissing, in Northern Ontario, has, for many years, attracted world-wide attention, in the first place on account of their immense and apparently inexhaustible character, but latterly because of the much more extended use of nickel, especially as an alloy with steel, to improve the qualities of the latter. The recent agitation for the imposition of an export duty on nickel ore and matte has, at least, resulted in drawing public attention to the fact that Canada has, for some time past, been one of the two great sources of nickel in the world, and at the present day produces more than half of the world's consumption of this metal. The history of the development of nickel mining in this region is inseparably bound up with that of copper, for the two minerals are always present in such intimate association with one another, that, in abstracting their metallic contents, they are subjected to the same metallurgical processes.

The existence of workable deposits of copper in this reigon was a fact that had long been known, and as far back as 1770 a company had been formed and attempts made to mine this metal, but the difficulty of procuring and maintaining miners, at so great a distance from any centre of civilization, the remoteness of any market for the ore, as well as the absence of facilities for transportation, were in themselves amply sufficient causes, if none other existed, to render these first attempts abortive. However, in 1846, owing to the activity in prospecting and locating mineral lands on the southern shore of Lake Superior, and a favourable report by Mr. W. E. Logan, then newly appointed Provincial Geologist, some enterprising Canadians banded themselves together into two associations called 'The Montreal Mining Company,' and 'The Upper Canada Mining Company.' The former company purchased, amongst others, what was then known as 'The Bruce Mines location,' and, on account of the apparent richness of the deposit, decided to commence active work at this locality, while the Upper Canada Company proceeded to develop and work what was known as the 'Wallace mine,' near the mouth of the Whitefish river, on Lake Huron. The Wallace mine was the choice of a number of locations, owned by the same company, on the north shore of Lake Huron, and was selected on account of its promising character and proximity to civilization. It is chiefly remarkable as having been the first place in Canada in which the presence of nickel was detected. After sinking a shaft to the depth of between 60 and 90 feet, and the opening up of a few pits to test the size of the deposit, all work was abandoned and has not been resumed since, as the quantity of ore encountered in these operations did not seem to warrant any further expenditure.

In his report for 1856, Mr. Alex Murray (1) thus refers to certain outcrops of sulphide bearing rocks which were long afterwards shown to be the southwestern extension of the now famous Creighton Nickel mine. 'At the fifth mile a dingy green magnetic trap, with a large amount of iron pyrites, forms a ridge, and that rock with syenite continues in a succession of ridges to the seventh mile, beyond which the country becomes low and marshy. Previous to my visit to Whitefish lake I had been informed by Mr. Salter that local attraction of the magnet had been observed by himself, while he was engaged in running the meridian line, and he expressed it to be his opinion that the presence of a large body of iron ore was the immediate cause. When, therefore, I came to the part indicated by Mr. Salter I made a very careful examination, not only in the direction of the meridian line, but for a considerable distance on each side of it, and the result of my examination was that the local attraction, which I found exactly as described by Mr. Salter, was owing to the presence of an immense mass of magnetic trap.

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(1) Rep. Geol. Surv. Can., 1853-56, pp. 180-181.

'The compass was found, while traversing these trap ridges, to be deflected from its true bearing upwards of ten degrees at several parts, and in one place it showed a variation of fifteen degrees west of the true meridian, or about twelve degrees from the true magnetic north. Specimens of this trap have been given to Mr. Hunt for analysis, and the result of his investigations shows that it contains magnetic iron ore and magnetic iron pyrites, generally disseminated through the rock, the former in very small grains; titaniferous iron was found in association with the magnetic ore, and a small quantity of nickel and copper with the pyrites. It was remarked that, notwithstanding the powerful influence of this magnetic mass in causing a general local attraction, the contact of fragments of it with the compass, although producing a slight effect, rarely occasioned any remarkable agitation of the needle.'

The line referred to in the above description was what was once known as 'Salter's Meridian line,' and the exact position of these outcrops of mineralized 'trap,' on the line, is in the first concession, on the boundary between Snider and Creighton townships. It can thus be seen, that even at this early period of its history the officers of the Geological Survey were aware of the existence of nickel in this region, and had pointed out the probability that workable deposits would be found. (1)

Years passed by, and the inaccessible nature of the country deterred prospectors from making any very detailed exploration or examination, so that it was not until 1883, when the Canadian Pacific railway was in course of construction, that the first discoveries of any consequence were made, since which time the whole belt characterized by the presence of the Huronian rocks in the Sudbury district has been overrun with eager prospectors and miners.

A not infrequent accident in newly settled districts led to the first important discovery. Judge McNaughton, late Stipendiary Magistrate at Sudbury, had been lost in the woods to the west of the town, and a diligent search was at once instituted for him. A party consisting of Dr. Howey and two others found the judge seated on the small eminence which then marked the site of what is now known as the Murray mine. Dr. Howey's natural curiosity and geological turn of mind are well known to all his friends, and it is not surprising, therefore, that having overcome his anxiety on the Judge's account, he should turn his attention to the neighbouring rocks. Looking down at the knoll which had served as a resting place for the tired wanderer, he noticed that the rock composing it contained abundant impregnations of what appeared to be a valuable ore of copper. More critical examination still convinced him that he had discovered a mine, and hastily securing some representative samples he exhibited them to Drs. Girdwood and Selwyn, who happened to be in the neighbourhood, and either of whom he considered fully competent to pronounce with authority as to the economic value or possibilities of his find. Dr. Girdwood, it may be remarked, was, at the time, one of the chief medical advisers of the Canadian Pacific railway, and a well known authority on chemistry and mineralogy. Dr. Selwyn, then Director of the Geological Survey, accompanied Dr. Girdwood, in order to obtain the necessary transportation facilities, enabling him to make a geological reconnaissance of the area in the vicinity of the railway. To Dr. Howey's surprise they informed him that the pyrrhotite which formed such a large proportion of his samples was practically valueless, that the only metal of importance which might be present in such a mineral was nickel, and that past experience with similar ores in Canada and elsewhere had taught them that this was always present in such small amount as not to permit of its profitable extraction. Turning their attention to the chalcopyrite, which was also represented in his samples, both these gentlemen agreed that although it was a valuable ore of copper the mineral was not present in sufficient quantity to pay for working. Thoroughly convinced of the soundness of their advice, but disappointed at the unexpected result, Dr. Howey took no further action in the matter, ridiculing in a quiet way the earnest and persistent efforts of others to interest capital in the immense economic possibilities of this and similar deposits afterwards found. One can imagine his chagrin, therefore, and sympathize with his mortification, when subsequent development demonstrated that both these gentlemen, whose scientific attainments could not be called in question, had been rather hasty in their judgment, although from a wide experience with the composition of pyrrhotites in general they had been right in thus expressing their opinion.

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(1) Rep. Geo. Sur. Can., 1848-49, p. 63.

Early in 1884, the Canadian Pacific railway made a cutting for their main line through this small hill (Murray mine), about 3½ miles northwest of Sudbury, and on July 12th of the same year Dr. Selwyn made a careful examination of the location, and stated to the writer, some years afterwards, that he had pronounced the lode to be one of the most promising he had yet seen in Canada. No such opinion, however, was ever published, although it is quite possible that the greater facility of examination caused by the cutting for the railway, and the massiveness of the deposit thus exposed, reversed his previous judgment of the ore body in question. (1)

Other discoveries soon followed, and the McConnell, Lady Macdonald, Stobie, Blezard, Copper Cliff and Evans mines were all located. At first the wildest notions were entertained as to the extent of these deposits, and the most exaggerated reports circulated as to their value. It was even confidently asserted that these were immensely important discoveries, and would revolutionize the whole copper trade and render other mines then in operation quite unremunerative. Rounded hills of gossan, indicating the presence of the more solid and unaltered ore beneath, occur at intervals for miles in a southwesterly direction, conforming rudely to the strike of the stratified or foliated rocks in the vicinity. This circumstance is all that seems to have justified the early discoverers in describing the deposits as veritable mountains of solid ore, many miles in extent and hundreds of feet thick. During the interval which has elapsed since the first discovery was made prospectors have not been idle, and their efforts have been rewarded by the location of three large belts or masses of the sulphide bearing norite. Until lately these have been considered as entirely separate and distinct from one another, but the later geological work is tending to prove their connexion as one continuous ellipsoidal band, the central portion of which is now occupied by tufaceous slates and sandstones, coloured provisionally as of Cambrian age.

The history of the development of mining in the Sudbury district is, in the main, that of the Canadian Copper Company, for it was the first combination of capital which seriously undertook the business of mining in this area, while, at the same time, having the distinction of being the only corporation which has continued its operations without serious interruption, from the commencement until the present time.

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1. A specimen collected at the time by Dr. Selwyn from the cutting on the railway at the Murray mine was examined by Dr. Hoffmann who says 'It consisted of magnetic-pyrites and copper-pyrites, in association with a dark grey fine-grained diorite and a greyish green chloritic schist; a few of the fragments were, in parts, coated with hydrated peroxide of iron. Some specimens of the magnetic-pyrites from this deposit contained numerous flakes of molybdenite. It was found to contain after drying at 100° C., (Hygroscopic water=0·85 per cent.)

Iron	27·35
Copper	9·08
Sulphur	18·69
Insoluble matter (gangue)	36·63
Gold	mere traces.
Silver	2·187 oz. to the ton of 2,000 lbs.

(Ann. Rep. Geol. Surv. Can., Vol. I., 1885, Part M, pp. 19-21.)

The McAllister mine, later called the Lady Macdonald mine, (now No. 4 mine of the Canadian Copper Company group), situated on the north side of the lake of the same name, on lot I, con. III, of the township of Snider, was the first property on which any work was done in the summer of 1885, although later in the fall the Evans mine, about two and a half miles farther south in the same township, was opened and some preliminary tests made. On January 5, 1886, the Canadian Copper Company was formed, with a subscribed and paid-up capital of $2,000,000, which was afterwards increased to $2,500,000, to operate the Copper Cliff, Stobie and Evans mines.

On May 1st, 1886, work was started in earnest at the Copper Cliff mine, near the north end of lot 12, con. II, of McKim township, and the first shipments of ore made from the district were obtained from the surface openings of the original Copper Cliff mine. Later on in the same year both the Stobie and Evans mines were opened up, and these three mines together produced all the ore treated in the smelters at Copper Cliff, until the year 1898. The first blast furnace installed at the old or East Smelter was blown in on December 24, 1888, this being augmented under the same roof by a second blast furnace, which was started on September 4, 1889. During 1896 and 1897 diamond drill exploratory work was undertaken in connexion with the deposits afterwards known as the No. 1 and No. 2 mines with their extensions, and in 1898 many of these openings produced a considerable quantity of high grade ore, but, with the exception of the deposit at No. 2, there was apparently no very large or continuous body encountered, for they were soon abandoned and are now completely dismantled. About the same time what is now the largest open pit of the whole group of the Copper Cliff mines (No. 2) was started in earnest, soon supplying a very large quantity of ore, which, however, contains a considerable admixture of rocky matter. The Evans mine, although with some rather serious interruptions, continued to furnish ore until late in the fall of 1899, when it closed down, and to all appearances has been permanently abandoned. The engines, boilers and other machinery have been removed, and the rails of the spur connecting the mines with the main line of railway have all been torn up and carried off to be used elsewhere. In the fall of 1899 preparations were made for opening up the Frood mine (No. 3), situated a little over a mile southwest of the Stobie mine, on lot 6, con. VI, of the township of McKim, and early in 1900 this was added to the list of producing mines. During 1899, and succeeding seasons, many of the openings northwest of No. 2 mine, as well as some of the pits and shafts known as the Clarabelle group of mines, were being operated at one time or another, and added materially to the reserves of ore, but all of these were shut down in the spring of 1902, when the business of the company was being curtailed, pending reorganization and consolidation of the various interests. In July, 1900, the work of stripping at the Creighton mine was begun, and in August of the following year ore was shipped for the first time to the roast yards at Copper Cliff. The Creighton mine is undoubtedly the largest mine in the district of which we at present have knowledge, and from the very beginning of operations has produced very large quantities of the almost pure sulphides, with little or no rocky admixture. It is especially valuable as carrying a high percentage of nickel, with a very much smaller proportion of copper. The mine is situated on the north half of lot 10, concession I, of the township of Snider, about six miles in a straight line west of Copper Cliff station. The ore, when mined, is carried on cars over the Manitoulin and North Shore railway, on the north side of which the mine is located, to Clarabelle junction, where connexion is made with the railway owned by the Canadian Copper Company. Before the opening of the Creighton mine the Stobie had the distinction of having supplied the largest quantity of ore of all the Canadian Copper Company's mines, and, with the exception of some minor stoppages, this mine was in continuous operation from the date of its opening, in 1886, until November, 1901, when it closed down and has remained so ever since. The reason for this cessation of operations does not appear to be that the end of the deposit has been reached, but because the quality of ore which it supplies is not needed in the present smelting operations. The Creighton mine is at present the main source of supply, and this mine with its equipment allows for a production of between 500 and 600 tons of ore per day, and Dr. Coleman is authority for the statement that for some time in 1902 the output from this mine alone reached 17,000 tons per month. The old or original Copper Cliff still continues to supply about 1,000 tons of ore per month, obtained mainly from the 13th and 14th levels, the latter workings being 1,052 feet below the surface; but even at this depth the ore body shows no serious diminution, either in size or richness. No. 2 mine and the Frood (No. 3) complete the list of mines from which at present the supply of ore is drawn. The mines of this company not in use at present must not all be considered as having been permanently abandoned, but the openings now utilized produce an ample supply of the sulphide material of the various grades suitable for smelting.

This activity in mining at Copper Cliff, and the steady increase in the production of ore, necessitated constant additions to the smelting equipment, as well as the erection of new and suitable buildings for the accommodation of the new blast furnaces. We thus find, that besides the enlargement of the old or East Smelter, where three new furnaces were installed in addition to the two already mentioned, an entirely new structure, known as the West Smelter, was built in 1899. At first this building had room for only four furnaces, but this was quickly enlarged, and the furnace capacity doubled. The site chosen for this new building was on the slope of the hill about 300 feet southeast of the No. 2 mine rock house, the deep valley to the south providing a convenient and ample dumping ground for the slag.

After the inauguration of this smelter the one at the east end of the works was gradually abandoned, and the whole plant has been removed to the site of the new building. The work done at this place, since the suspension of operations in the beginning of 1902, has been rather spasmodic, and has consisted mainly in the production of a low grade matte known as 'split matte.'

Thus, several of the furnaces at this smelter were being employed in producing this matte from June, 1902, until the end of the year. In addition two of the furnaces have been engaged from time to time making experiments in the way of smelting the ore pyritically. It is hoped, by this method, to reduce the coke to 3 or 4 per cent of the charge, by using a hot blast and an oxidizing atmosphere in the blast furnace, and utilizing the heat developed by the burning of the sulphur and iron of the ore, for the smelting. In the fall of 1900 the plant of the Ontario Smelting Works was installed by the Orford Copper Company, an organization closely related to the Canadian Copper Company. The works, as completed, are designed to further refine the first or lower grade matte, produced by the blast furnaces of the Canadian Copper Company, using as a flux the siliceous ore from the Massey Copper mine.

Perhaps, the most important event in the development of the nickel industry, either in this district or elsewhere, occurred in April, 1902, when, after negotiation covering a period of several months, the International Nickel Company was organized under the laws of the State of New Jersey, to consolidate and control the nickel production of the world. The following properties were included in the new organization:—The Canadian Copper Company; the Orford Copper Company, with reduction works at Bayonne, N.J.; the Anglo-American Iron Company, and the Vermilion Mining Company, in Canada; the American Nickel Works, in Camden, N.J.; the Nickel Corporation, Limited, and the Société Minière Caledonienne, in New Caledonia. During 1902 and 1903 mining operations were considerably curtailed, except in the case of the Creighton mine, where the production has been brisk ever since it was first opened. This has permitted certain very necessary explorations of many of the ore deposits, by diamond drilling and testing shafts. The results of these experiments have added very largely to the detailed knowledge, not only in regard to the size and shape of the deposits already known, but has succeeded in revealing the presence of considerable bodies of ore whose presence had not been suspected.

Such, in brief, is the record of the principal events in the development of the mining and metallurgical operations of this pioneer company, in the nickel industry in Canada. From the start their work has always been characterized by energetic and business-like methods, and if at the present time they seem to have gained control of more than their fair share of the available nickel bearing area, which likewise includes many of the mines producing the largest supplies of high grade nickel ore, the result must not be attributed to chance or a series of fortunate circumstances, but is rather the strongest evidence of the keen business foresight of the originators of the enterprise, and an abiding faith in the permanence of the nickel mining in this district.

It must not, however, be assumed that all of the available or even important deposits of nickel-copper sulphides have passed under the control of the International Nickel Company, for besides the Victoria mines of the Mond Nickel Company, which still contain a very large reserve of high grade ore, there are many others throughout the district which are capable of economic development as more or less permanent mines. Suspension of operations, so often recorded in the history of the mining development of the district, does not in all or even a majority of cases imply a failure in the ore supply, but is oftener to be attributed to a waste of capital, owing to lack of business judgment, and the need of a technical knowledge of the difficulties to be encountered in both the mining and smelting departments. Moreover, many of the deposits have been condemned because they failed to give a proper return for the capital invested, when all that was available of the latter was utilized in costly experiments to discover new methods of smelting or refining. Past experience in this district has shown that success and permanency in the mining and smelting operations of any company can only be secured by the possession of large reserves of ore, preferably obtained from different mines or deposits. In this way not only is a constant supply of ore assured, but diversity in composition is possible, thus enabling a judicious selection of the different grades, whose mixture in the proper proportions promotes successful and economic smelting.

In addition to the deposits which are still available along the

Southern range, most of which are in various stages of development, there are other apparently very large and important ore bodies situated along the Middle range (in Levack township); and others again on the Northern Nickel range which are certainly worthy of close attention and which seem destined, in the near future, to be worked as mines. The lack of transportation facilities has, up to the present, prevented any deep mining work being done, but the surface indications and geological conditions are entirely favourable to the existence of large ore bodies, which, although perhaps not attaining the phenomenal dimensions of the Creighton property, will nevertheless prove of sufficient magnitude to form valuable mines.

Henry H. Vivian & Co.

The incidents attending the discovery of the deposit which was afterwards known as the Murray mine have already been related, as also the fact that it was located over a year previous to either the Copper Cliff or Stobie mines. In spite of this circumstance, however, and its advantageous situation on the main line of the Canadian Pacific railway ,no mining of any importance was done in connexion with this property until early in the year 1889. During the whole of this season, however, it was prospected under bond by H. H. Vivian & Co., of Swansea, Wales, and in October of the same year it was sold outright to this company by the original owners. The mine is situated on the north half of lot 11, con. V, of McKim township. All the necessary machinery, buildings and other adjuncts were installed, and preparations made for carrying on the business of mining on an extensive scale.

The first blast furnace at the Murray mine was blown in about the end of September, 1890, and put to work on some ore which had been previously roasted. The general practice followed by this company in their smelting operations consisted in the production of a comparatively low grade blast furnace matte (averaging 9 4 per cent nickel and 4·7 per cent copper), thus preventing an undue loss of the metals in the slag, and subsequently bessermerizing this into a second or higher grade matte (averaging nearly 75 per cent of the combined metals, or about 49 per cent nickel and 26 per cent copper). For this second concentration of the metallic contents the Vivians were the first to make use of the Manchés furnace or converter, in 1891. Mining and smelting operations were continued, although with some minor interruptions, from 1889 until 1894, when the works were finally closed down. Between August, 1896, and January, 1897, however, the smelter was engaged in producing matte from about 6,000 tons of ore which had been roasted by the Vivians. This product was shipped to Mr. Joseph Wharton, of Camden, N.J., to whom it had been sold.

The purchase of the Murray mine by this old established and well known firm of Welsh smelters was regarded by all as marking a distinct epoch in the history of nickel mining in Canada. Their wide experience in all branches of metallurgical industry seemed to augur well for the success, not only of their own individual enterprise, but to others similarly engaged in the mining and smelting of these nickel and copper sulphides. The difficulties which always attend the initiation of a new undertaking were in evidence from the very beginning of the business of nickel mining, and were of that nature which required the exercise of just such ripe technical knowledge as the Vivians were sure to possess. Moreover, such a significant acknowledgment of the success and permanence of nickel mining in Canada, on the part of a firm whose sphere of activity in mining and smelting had extended to all parts of the known world, could not fail to have a most marked influence on all subsequent mining operations in the district. It was, therefore, to say the least, bitterly disappointing, that from the very outset a seeming lack of energy, and often even of ordinary business ability, on the part of those who had control of the work, was a subject of common remark, being in marked contrast to the alert methods characterizing the operations of the rival corporation, the Canadian Copper Company. This was evident in almost every department of the work, and the apparent lack of technical knowledge and business capacity on the part of this firm, from whom so much had been expected, could not be very well understood by the ordinary observer. On the other hand, the management entrusted with the conduct of affairs at the mine complained of want of interest and attention on the part of the authorities in England, but, whatever the real cause, or combination of causes ,the enterprise was not attended with the success anticipated, and which should have been reasonably expected. The final decision of the company to close down and withdraw from the business of mining in Canada, came as a distinct shock to all those who were interested in seeing the permanency of the nickel mining established. The failure of these operations must not, therefore, be attributed, as some have supposed, to the diminution in depth of the ore body or to abundant rocky admixture, although these, no doubt, contributed to a certain extent to bring about the undesirable result. It seems altogether reasonable to suppose that a considerable quantity of ore is still present, both in the lower levels of the mine, as well as below these workings at depths which have not yet been reached by the mining explorations so far undertaken, which could be profitably mined in conjunction with other deposits. In this respect the Vivians were at a manifest disadvantage as compared with the Canadian Copper Company, the varied composition and character of the ores from whose different mines permitted, and even favoured, the mixtures which are seemingly so essential for the successful and economical smelting of these sulphide ores. In addition to the Murray mine the Vivians owned the nickel and copper deposit known as the Lady Violet mine, situated on the north half of lot 1, con. IV, of the Township of Snider, about 1½ miles southwest of the Murray mine. The mining, however, undertaken at this locality consisted chiefly of stripping, the sinking of trial shafts, and other preliminary development work. A blacksmith's shop and some temporary residences were the only buildings erected.

Some rather extensive diamond drill exploration work was subsequently undertaken by order of the Board of Directors in England, at both the Murray and Lady Violet mines, but, unfortunately, the different sites for the drill, as well as the angles of inclination and direction of the bore holes, were determined by some of these same directors in England, whose only means of guidance in this section seems to have been maps of the two properties in question, but without any very extended personal knowledge of the actual geological conditions prevailing at these places. As might have been expected, from operations carried on under such adverse conditions, no important ore bodies were encountered, nor was any information of material value obtained, which might be of assistance either to the owners or to any prospective buyer. The diamond drill used belonged to the Ontario government, and was leased to the Vivians under the usual conditions of working in 1898. Boring was begun on the 2nd of December, 1898, and the work continued until the 16th of June, 1899, the number of days of actual boring being 212, of 10 hours each. In all, eight holes were put down, having an aggregate depth of 1,146 feet, which cost on an average $2.65 per foot. (1)

Since the abandonment of actual mining the property has been under the charge of Mr. G. H. Behema, who has been continuously employed looking after the various buildings and machinery, while a pump has kept most of the levels comparatively free from water.

Dominion Mineral Company.

The Dominion Mineral Company commenced mining operations in the summer of 1899, on a deposit of nickel and copper ore known as the Blezard mine, occurring on lot 4, con. II., of Blezard township, about 1¼ miles north of the Stobie mine, at the southern edge of the Main or Southern range of norite, which here comes in contact with the older diorites and hornblende schists. A smelter was soon built, with a furnace capacity of 120 to 150 tons daily. Four shafts were sunk at this mine, the deepest of which seems to have reached a point 172 feet below the surface. Most of the ore secured, however, was by means of a series of large open pits which are at present filled with water. The 'kies' or metallic portion of the ore thus obtained is said to have averaged about 4 per cent nickel and 2 per cent copper. For reasons which have been differently stated mining operations were discontinued in the summer of 1893, and have not been resumed since. The smelter, however, at this mine, was kept running until July, 1895, on ore brought chiefly from the Worthington mine. The total production of ore cannot be accurately given, but the figure of 100,000 tons is certainly somewhat below the actual output. The Worthington mine, also worked by the same company, is situated at a station of the same name, on the Sault branch of the Canadian Pacific railway, twenty-five miles west of Sudbury. The mine itself, consisting of two shafts. lies close to the line between lots 1 and 2, con. II, of the township of Drury. It was discovered at the time of the construction of this branch by Mr. James Worthington, one of the railway contractors. Actual mining was started on this property in the summer of 1890, and continued without much interruption until the middle of September, 1894, when operations ceased, and with the exception of a short time in 1902, when the mine was pumped out for purposes of inspection, no work of any consequence has since been done. From the two shafts, one of which reached a depth of 100 feet, and the other 175 feet below the surface, as well as from two adjoining stopes and connecting levels, a considerable amount of unusually high grade ore was obtained, which has been estimated by Dr. Coleman at 25,000 tons. The pyrrhotite occurring at this mine is often phenomenally high in nickel, chiefly owing to abundantly disseminated pentlandite, and the first recognition of this mineral in the district was by Dr. T. L. Walker, in the ore procured from this mine by the writer in 1891, and to which reference has already been made. The analysis of this pentlandite by Walker showed 30 per cent nickel, but an examination of some large masses of ore obtained at a depth of 85 feet below the surface, and consisting of pyrrhotite with a considerable proportion of pentlandite, which could be readily discerned, showed 17·48 per cent nickel. In 1891 a shipment of raw ore was made from this mine of 123 tons, which contained 10 per cent nickel and 3 per cent copper. Large masses of practically pure chalcopyrite were also obtained, and a considerable quantity of such ore is stated by Manager Attwood to have been shipped, assaying 18 per cent copper and 2·5 per cent nickel.

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(1) Ann. Rep. Bur. of Mines, Ont., 1901, pp. 53 and 55.

In the fall of 1895 some development work was done by this same company, at the Cameron mine, on lot 7, con. 1, of Blezard township, nearly two miles southwest of the Blezard mine. A shaft was sunk a distance of 65 feet with a drift 66 feet in length. The real reason for the cessation of work at both the Worthington and Blezard mines is very difficult to ascertain, but bad business management was responsible in large part for many of their difficulties during these mining operations. Individual members of the company state that the present idleness of these properties is because no decision satisfactory to all parties can be reached by the board of directors, so that working under these conditions is impossible, and they would be inclined to sell.

Some of the other companies who carried on mining, and in some cases smelting, operations for a time, shortly after the recognition of this area as a mining district, deserve a passing mention in this connexion.

One of these, the Algoma Nickel Company, in 1891, under an option secured from the owners of the property, sank four shafts varying in depths from 12 to 35 feet and aggregating 84 feet in all, besides some smaller openings or test pits on lot 11, con. V, of the township of Lorne. No large body of ore was, however, met with as a result of this development work, the sulphides apparently occurring as unusually rich impregnations, which, if continuous, might prove an economic possibility. These sulphides occur in connexion with what is seemingly the southwestern extension of the same mass or band of norite on which the Worthington and Mitchener mines are situated. Work was abandoned, leaving ore piles aggregating about 500 tons in weight. Assays of an average sample in the laboratory of the Survey showed 1·95 per cent nickel, with traces of cobalt.

The Drury Nickel Company purchased the deposit known as the Chicago or Travers mine in 1890, and began active mining in February, 1891. This mine is situated on lot 3, con. V, of the township of Drury, about 5 miles north of Worthington station, on the Sault branch of the Canadian Pacific railway. Most of the ore was mined by means of open cuts, one of which had a depth of 30 feet, length 60 feet and width 30 feet, from the bottom of which a shaft 8 by 12 feet was sunk to a depth of 60 feet. Another open pit measured 40 feet in length, 80 feet in width and 30 feet in depth. From these openings 3,500 tons of ore were obtained, and reduced to matte in a water-jacketed furnace capable of treating 60 tons in 24 hours. A roast-yard was prepared, suitable buildings erected, and the plant installed necessary for permanent mining, but in spite of all this the mine closed down in 1892. In 1893, after lying idle for nearly a year, some additional mining and smelting was undertaken, but this was also soon abandoned. On May 20, 1896, work was again resumed, the company being organized under the name of the Trill Nickel Mining and Manufacturing Company, and the deposit itself was rechristened the Inez mine. An elevated tramway, 4½ miles long, was built from Worthington station, for conveying supplies to the mine, and the product of the mine, in turn, to the station. It was possible, by means of this tramway, for a single horse to haul two cars, each containing two tons, and to make two round trips each way daily. Mining and smelting continued briskly again, for a while, but before August, 1897, work was again stopped, and has not since been resumed.

From time to time mention is made of the 'Big Levack properties,' thus referring to certain deposits of nickeliferous pyrrhotite which were discovered early in the history of the district in the township of Levack, but none of which have been sufficiently developed to be dignified by the name of 'mine.' From time to time, however, considerable work has been done and examinations made with a view to possible purchase, but for various reasons the properties are now (1901) lying idle and without any present prospect of being opened up in the near future. The deposits in question are situated along the northern junction of what has sometimes been called the Windy Lake eruptive or Middle Belt of the nickel bearing norite, although it is possible that this is a portion of the huge ellipsoidal band, and the southwestern continuation of the Northern Nickel range. The surface indications are undoubtedly among the best in the district, and the development work so far undertaken has exposed a very large amount of almost pure nickeliferous pyrrhotite, with little or no rocky admixture. The ore-body has the additional advantage that chalcopyrite forms only a comparatively small proportion of the whole. The first, and probably the most extensive mining exploration work in connexion with these properties, was undertaken in 1891, and a report made by Mr. A. Merry, of H. H. Vivian and Company, for the owners of the property. This work consisted of extensive stripping, and the removal of portions of the overlying drift material, the opening up of numerous cross cuts, trenches and test pits. The average assay of a number of typical samples, made by Mr. Merry, showed the presence of 3·86 per cent of nickel in the pyrrhotite, with 0·81 per cent of copper. Assays made in the laboratory of the Survey show the nickel to vary from 1·96 to 4·13 per cent, the lower figure containing considerable gangue, while the higher results were obtained from the solid, coarse-grained pyrrhotite. Early in 1901 some of these locations were examined by means of diamond drill exploration, under option by the Mond Nickel Company, but to the disappointment of all who were concerned in the welfare of the district this company decided to abandon their option, and the property was again thrown on the market. It is manifestly unwise, as a rule, to condemn as worthless the testimony afforded by diamond drill exploration, especially when such work is under the superintendence of men thoroughly experienced in the mode of occurrence of the class of deposit to be tested, but an inspection of the work performed at this time seems thoroughly convincing that much of what was done added very little, if any, information to what we already possessed in regard to these deposits, or than can be secured without such costly assistance. We are, therefore, still in the dark as to whether or not there are any large or continuous bodies of ore at these places, and if the former, as to their most likely disposition. All geologists who have visited these deposits, and especially those who have had wide experience in the district, are agreed that large and valuable orebodies are likely to occur at this place. The rock is the usual norite, with which all the other mines of the district are associated, while the contact is well and sharply defined, and the differentiation pronounced. The area covered by the nickel bearing norite is very large, and no other deposits have been found in connexion with this eruptive. The angle of dip to the southeast is unusually low for the district, and this fact has to a large extent prevented its successful exploration. The development work, as well as the borings undertaken by the diamond drill, seem to incline the casual observer to the conclusion that the deposit is a 'pancake' and has no great depth or permanence. A careful study of the attitude of the outcrops of rock, as well as their surface outline in the immediate vicinity of the sites chosen for drilling purposes, is convincing that no deep deposit need be expected in their vicinity, while, on the other hand, it seems reasonable that the main body of the sulphides is concealed beneath the drift, at the base of the hill, where no trials whatever have been made. A shaft sunk here and continued with the granite-gneiss as a footwall, with drifts outward towards the main mass of the norite, would show definitely and finally not only if any large and continuous orebody is present along this line of junction, but at the same time would secure a considerable amount of ore, which could afterwards be used.

In 1891, a shaft was started on the Davis property, known as the Sheppard or Beatrice mine. This deposit is situated along the northeastern extension of the same line of junction as the Blezard mine, between the norite and greenstone. It is on lot 1, con. III, of Blezard township, nearly two miles northeast of the Blezard mine, with which it is connected by wagon road. The shaft, 10 by 12 feet, was sunk to the depth of 100 feet, with three small drifts, aggregating 34 feet. Work, however, was not continued after April, 1893.

In the same year, (1891), a shaft was sunk and considerable development work done by the Emmons Metal Company, on the property afterwards known as the Macdonell or Gersdorffite mine, situated in the southeast corner of lot 12, con. III, of the township of Denison, and about one mile and a half northeast of Worthington station. This locality is remarkable as having furnished the first specimens of the rich nickel minerals, niccolite and gersdorffite, in the district, but as no large body of ore was discovered mining operations soon came to an end.

In 1894, the deposit known as the Trillabelle mine was opened, and a shaft 60 feet in depth sunk on the deposit. This mine is situated on lots 10 and 11, con. III, of the township of Trill, and is connected by wagon road, by way of the Inez or Travers mine, with Worthington station, which is about 13 miles distant.

In 1898, the deposit which was named the Kirkwood mine, situated on lot 8, con. III, of the township of Garson, at the southern edge of the main or southern belt of norite, along the same line of junction as the Blezard and Beatrice mines, was opened. Three shafts were sunk, the deepest of which was rather less than 50 feet. A substantial rock house and other suitable mining buildings were erected, but for lack of sufficient capital the work has not proceeded further.

On October 5, 1899, the Great Lakes Copper Company was organized, and purchased the property known as the Mount Nickel mine, comprising lots 5 and 6, con. II, of the township of Blezard. They also purchased what was known as the 'Trill Property,' consisting of lots 9 and 10 in cons. III and IV, of the township of Trill, in the district of Algoma. The Mount Nickel mine was chosen as the scene of the first mining operations, and this deposit was developed by means of two open cuts and a shaft, which eventually reached a depth of about 165 feet, with certain levels and drifts, from all of which considerable ore was obtained. It is also stated that diamond drill explorations subsequently undertaken revealed the presence of a good supply of ore. The mine was equipped with all the machinery and other appliances for carrying on extensive mining operations. The smelting works were built from original designs by Anton Graf of Vienna, and it was proposed to produce high grade matte at one operation from ores which had received no previous roasting. This method of smelting failed, and in May, 1901, all operations ceased, and have not been resumed since.

In the latter part of 1899 it was announced that a strong company, under the title of the Hoepfner Refining Company, with a capital of $10,000,000, had been formed in Hamilton, to refine nickel-copper mattes and zinc ores. These metals were to be recovered by electrolytic methods discovered by Dr. Carl Hoepfner. The Nickel Copper Company, of Hamilton, also organized about the same time, were to furnish the necessary supply of nickel-copper matte. Unfortunately, however, Dr. Hoepfner was unable to so perfect his methods as to permit of its economic application on a large scale and the Nickel Copper Company took the matter of experimenting into their own hands. The services of Mr. Hans A. Frasch were obtained, who devised what is known as the 'Frasch Process.' This method likewise, although possible under ordinary conditions of laboratory practice, as was demonstrated at a public exhibition held on September 3, 1900, was not capable of commercial application. The operations of the Nickel Copper Company came to an end in 1901, owing to the complete failure of the new self-roasting plant erected near Worthington station.

LAKE SUPERIOR POWER COMPANY.

For some time after the opening of the pulp mills at Sault Ste. Marie the Lake Superior Power Company were content to manufacture mechanical pulp, but discovering that there was a large and growing demand for sulphide pulp it was decided to at once enter upon its manufacture. The proximity of the sulphide deposits at Sudbury suggested that the sulphur which was necessary for the production of this pulp might be most profitably extracted from these ores, and at the same time yield a by-product of very great value. The preliminary experiments with the nickeliferous pyrrhotite were convincing that sufficient sulphur dioxide could be procured from this mineral by roasting, while at the same time the roasted ore or residue, consisting essentially of a mixture of iron and nickel with only a comparatively small percentage of sulphur, could be mixed with lime and charcoal and smelted in electric furnaces to ferro-nickel. It was intended at the time to employ this alloy in large quantities. An inspection of all the available deposits of nickeliferous pyrrhotite seemed to indicate that the property afterwards known as the Gertrude mine was peculiarly adapted to meet the necessities of the case in hand. In 1899, therefore, the Lake Superior Power

Company purchased this mine, and immediately proceeded to develop the deposits which were situated on the S. ½ of lots 3, 4 and 5, of con. I, of the township of Creighton, a little over twelve miles west of Sudbury. The preliminary examinations and first development work showed an unusual predominance of a high grade nickeliferous pyrrhotite, with comparatively little of the objectionable copper in the form of intermixed chalcopyrite. As mining operations proceeded, however, more chalcopyrite was encountered, and the deposit gradually assumed the usual characteristics of those elsewhere in the district, and the copper contents assumed too large a proportion to permit of the successful carrying on of the first proposal. Repeated experiments were made with many carloads of raw material shipped to the works at the Sault for this purpose, but it was finally decided to adopt the ordinary process of smelting in use elsewhere throughout the district, producing a blast furnace matte averaging about 29 per cent of the combined metals, the proportion of nickel being about double that of the copper.

In 1900, the development of the Gertrude mine was continued, but the want of transportation facilities greatly hampered these operations. Two shafts were sunk, one attaining a depth of 120 feet, and the other of 80 feet, with several levels and drifts. In the spring of 1901 the Manitoulin and North Shore railway reached this mine, and work was conducted much more energetically. Roast yards were prepared, and the erection of a smelter commenced. In July of that year the Elsie mine, on the S. half of lot 12, con. V, of McKim, and about half a mile southwest of the Murray mine, was opened up. The ore was shipped in 50-ton steel cars to the roast yards at the Gertrude mine, and the first shipment of ore was made to this place on the 26th of October, 1901, on the completion of the switch which connects the deposit with the main line of the Manitoulin and North Shore railway. The smelter at the Gertrude mine was finished in June, 1902, and afterwards ran steadily throughout the year, converting 100 to 160 tons daily into standard matte. In November, 1902, all work was suspended at the Elsie mine, to permit of the needed removal of some of the mining buildings, whose safety was threatened by a continuance of the mining work. Later, in 1903, the whole of the mining operations in the Sudbury district shared the same fate in common with the other industries operated by the same company at the time of their failure.

MOND NICKEL COMPANY.

In 1889, Dr. Ludwig Mond, F.R.S., in collaboration with Dr. Carl Langer, while carrying on certain experiments for determining a suitable method for eliminating the carbon monoxide gases containing hydrogen, made certain observations which eventually resulted in the discovery of what has since been known as the Mond or carbon-monoxide process, for separating metallic nickel from copper, &c. In this process there were many technical difficulties to be overcome, so that, although a patent was applied for on the 12th of August, 1890, it was some years before it had reached such a stage as demonstrated its possibilities of commercial success. In 1892, an experimental plant, on a large scale, was erected at Smethwick, near Birmingham, England, and after several years of patient work, during which time the plant had to be several times remodelled in order to meet all the requirements of this somewhat delicate process, it gradually assumed its present shape. In 1898, it had reached such a state of perfection as to afford the most convincing proof that the process was able, not only to compete successfully in regard to cost of operation, but at the same time the metallic nickel produced showed, on analysis, a higher degree of purity than had yet been possible by any other known process.

The success of the method being thus assured, Dr. Mond began at once to make inquiries, with a view to obtaining an unfailing supply of nickel ore. Experiments conducted on the nickel and copper sulphide ores seemed convincing that such were peculiarly suited to treatment by the Mond process, so that it was decided to buy one or more of the best locations which were then available in the Sudbury mining district. At this time, and for some years previously, it was a matter of common gossip throughout this area that the McConnell mine or property, in the township of Denison, was one of the largest deposits of high grade ore which had yet been found, and attention was, therefore, directed to it with a view to possible purchase. After some negotiations, and a thorough investigation of the merits of these deposits, Dr. Mond decided to acquire these properties, and accordingly, in the summer of 1899, the necessary transfer was made. These mining locations had been under development for some time by their former owner, Mr. Rinaldo McConnell, and at the time they were sold to Dr. Mond explorations were being carried on by means of the Ontario government diamond drill, with a view to determining more definitely the position and extent of the various ore-bodies. The change in ownership, however, did not affect the progress of the work, which began on July 10, and finished on November 21, 1899. In this time seven holes were bored, the aggregate number of feet being 994, at an average cost of $1.75 per foot. In addition, two other drills owned by Dr. Mond were engaged more or less continuously during this and the two succeeding years, investigating these and other mining locations, in which Dr. Mond was interested. The main shaft and mining buildings of what were henceforth to be known as the Victoria mines are situated on the north half of lot 8, con. IV, of the township of Denison, while the smelter, offices and official residences were built on the north half of lot 8, con. II, of the same township, close to the 'Sault' branch of the Canadian Pacific railway, and a little over two miles south of the main openings.

Beginning in 1899 the work of opening up these deposits proceeded as rapidly as circumstances permitted. Extensive stripping of the deposits and other preliminary development work was undertaken; roads were opened up; a roast yard was levelled and otherwise prepared, and the necessary timbers secured for the numerous extensive structures contemplated.

During 1900 this work was continued, special attention being given to equipping the mines and smelter, the site of the latter being chosen close to Fairbank creek, on the Sault branch, 22 miles west of Sudbury. An aerial tramway, 11,000 feet in length, was installed by the Trenton Iron Co., of Trenton, N.J., to convey the ore from the rock house at the mines to the roast yard, which was first located close to the smelter.

On the 16th of October, 1900, the Mond Nickel Company, Limited, of London, Eng., was authorized, by license of the Lieutenant-Governor, to carry on business in Ontario. The incorporation of this company, with a capital of £600,000, was for the purpose of acquiring all the above property, plants, patents, and smelters belonging to Dr. Ludwig Mond in the Sudbury district.

Plant of the most modern type, for roasting, smelting, and bessemerizing the ore, was erected at Victoria Mines, under the direction of Mr. Hiram W. Hixon, formerly of the Anaconda Company, this equipment being the most complete and conveniently arranged which had up to that time been installed in the district. In addition substantial offices and tasteful dwellings, with all modern conveniences, such as water and electric light, have been erected for the accommodation of the staff and their families, and the site of pre-existing swamps and rocky hummocks was quickly filled in, levelled and transformed into an important village and business centre.

Early in 1901 the mine was in complete working order, and begining with February ore was regularly raised and transported by means of the aerial tramway to the roast yard. The smelter shortly afterwards commenced to turn out matte, by the Bessemer process, this product averaging about 80 per cent of combined nickel and copper, the former metal being usually present a little in excess. On 1st July, 1901, the head house or landing station at the roast yard was struck by lightning, and before adequate assistance could arrive, was burned to the ground. This temporary breakdown of the cable system, although greatly retarding mining operations at the time, was really a blessing in disguise, as it resulted in a decision to abandon this roast yard, the position of which on the immediate outskirts of the village had been a source of annoyance and inconvenience to the residents, who, during certain conditions of wind and weather, suffered greatly from the sulphurous fumes given off by the burning piles. The new site chosen consisted of a flat about half way between the smelter and the mine, which could be easily levelled, drained and otherwise prepared, this location being much more spacious and suitable in every way than the roast yard it was proposed to abandon.

During the winter of 1901 and 1902 the operations of this company, at the Victoria mines, were greatly curtailed, but the completion of the refining works in England, and the beginning of operations on a large scale at these works in April, 1902, gave a fresh impetus to all departments of mining activity. During the summer of 1902 the North Star mine, situated on lot 9, cons. II and III, of the township of Snider, and the Little Stobie mine, on the north half of lot 6, con. I, of the township of Blezard, were worked by this company. The ore, amounting to 4,724 tons obtained from the North Star, and 1,584 tons from the Little Stobie, was shipped to the Victoria mines for treatment. The bessemerized matte, as quickly as produced by the smelting works at Victoria mines, was shipped to Clydach, near Swansea, in Wales, where extensive works had been built for its treatment, calculated for an annual production of from 1,000 to 1,500 tons of metallic nickel, and 4,000 to 6,000 tons of copper sulphate. These works have been so designed as to render future extension easy and economical. The property at Clydach, including about 33 acres, on which the works are erected, has a frontage on the Swansea Valley canal, giving easy access to the port of Swansea, and is connected by a siding to the Midland railway. After a year's steady production from both mines and smelter all activity ceased in December, 1902, and although most of the higher officials were retained in office, no mining work of any consequence was undertaken until early in the spring of 1903, when work was again resumed and continued until November of the same year, when operations were again discontinued. It is currently reported that the real reason for these frequent interruptions in the mining operations was due to certain defects in the plant at the Clydach refining works, and it is also rumoured that after a recent breakdown in the plant there were over twenty cases of poisoning from the escaping gas, which resulted in several fatalities. It is confidently expected that a remedy will soon be found for this serious condition of affairs, and that the necessary alterations in the plant will again permit of its operation on an extensive scale, thus insuring a resumption of work at the Victoria mines.

The history of the development of mining in the Sudbury district has not, therefore, been an unbroken record of brilliant successes, but often quite the reverse has been the rule, and as may be noticed in the preceding pages the number of companies who for different lengths of time have operated in this area already constitute a formidable list. These failures, and the causes which have operated to bring about this untoward result, serve, however, to bring into strong relief the gallant and successful struggles of the only company which has been able to surmount the various difficulties to which the other organizations have successively succumbed; at the same time strengthening the belief that the crisis has been passed, and the industry has at last been established on a firm and permanent basis. It is true that certain details in regard to the extraction of the nickel are still in the experimental stage in order to determine, if possible, a more economical method, but there is no doubt whatever that the business of the mining and smelting of nickel is not only in a satisfactory condition but has reached such phenomenal dimensions that operations in other countries have, in consequence, been either greatly curtailed, or have ceased altogether, so that at the present time the supremacy of the Sudbury mining district as the world's greatest producer of nickel is unquestioned.

It may be well, in passing, to state some of the reasons which have contributed to the failures which have been so frequently recorded in connexion with the establishment of the Sudbury nickel industry. For some time after the beginning of mining work in this region the world's annual consumption of nickel did not exceed 700 or 800 tons of the pure metal, which amount could readily be produced by any one of the three companies then operating in the district. The demand for nickel was, therefore, so small and uncertain, that before the discovery was made of its advantageous employment as an alloy with steel, especially in the manufacture of armour plate, no great future seemed assured for the nickel industry, and even with this distinction in its favour no very marked increase in the demand for nickel could be noticed, and it took a number of years more before the consumption had increased to 1,500 tons per annum. By the time, however, this latter figure had been reached, it was certain that a constant and ever increasing demand for nickel was assured, on account of its general use in all kinds of steel where strength combined with lightness were the important factors. At the present time the consumption of nickel exceeds 10,000 tons per annum, and exhaustive experiments now being undertaken, under the auspices of the International Nickel Company, are stated, on the best authority, to give strong evidence of the superiority of nickel steel in bridge building, so that a much larger demand for nickel can be looked for in the immediate future. In addition, the recent decision of the Pennsylvania railway to use nickel steel rails, and the award of a contract for 9,000 tons of the same to carry 3·50 per cent nickel by this vast and progressive corporation, will no doubt give a fresh stimulus to the demand. The only anxiety which now exists, and which has often been urged against any large employment of nickel steel, relates to the sources of supply, and to the possible exhaustion of the nickel deposits now known to exist. All authorities are, however, in substantial agreement that the supply of high grade nickel ore contained in the Canadian deposits is practically unlimited, and at least amply sufficient for many years to come to supply the requirements of even much more extensive smelting operations than are now carried on in the Sudbury district. Besides, a demand for larger quantities of nickel will stimulate prospecting, not only in this region, but also in areas of similar crystalline rocks to be opened up in a very short time by the Grand Trunk Pacific and its branches, as well as by the Timiskaming and Northern Ontario railway, with the probable result that many more new deposits will be discovered.

Another fact which has contributed to a considerable extent to bring about the failure of some of the Sudbury mining concerns was the assumption by interested parties that each individual deposit of which they had the good fortune to obtain possession was a mine capable of producing a permanent and unlimited supply of nickel ore of the desired grade, the ore-body extending to unknown depths, and increasing both in quality and quantity with its downward extension. With such confidence in the size, permanency and suitability for smelting operations of the ore-bodies, it is not surprising that very often no special effort was made to obtain control of other available sources of supply, which were sure to be needed when extensive and long continued refining operations were in progress.

A third cause, which perhaps assisted more than any other to bring about the frequent suspension in mining and smelting operations already recorded, was the lack of the necessary technical knowledge and experience on the part of those who had the management of many of the organizations. The strong necessity of such information, in every department of mining and smelting, needs no special explanation or emphasis, but it was more than ever required for the successful treatment of these particular sulphide ores. Thus, some of the companies engaged in mining in the vicinity of Sudbury succeeded in reaching the stage of producing matte, but even these were obliged to sell this unfinished product to the various refiners, at prices which usually came far from realizing their expectations in this respect. The refiners were accused of reaping all the profits, which should have been shared with the producers, so that, very early in the history of the region, it was patent to every one that to share in the full benefits of the industry the same individuals or company must control the whole of the operations necessary to manufacture the finished product. Acting on this knowledge, therefore, many of the corporations engaged what was considered the most expert metallurgical advice, and numerous experiments were undertaken to determine an effective and economic process by which the nickel and copper could be extracted from these ores, and afterwards separated from one another. In this manner the too often very limited resources of these companies were taxed to the utmost, and any failure, even in the preliminary trials, to yield the decisive and satisfactory results looked for often resulted in the closing down and practical abandonment of the mines and works concerned. Finally, in more than one instance, the absence of sound business methods assisted very materially to bring about some of the disastrous failures which have been recorded in the foregoing pages.

General Physical Features.

The expression 'Sudbury Mining district' was applied as a term of convenient reference, soon after the discovery of these valuable mineral deposits, to designate that particular tract of country immediately surrounding and tributary to the town of Sudbury. It must not, therefore, be confounded with other areas of Northern Ontario to which the term 'district' has been applied, and which have been thus set apart, with definite boundaries, for electoral and other purposes. Roughly speaking it may be described as extending from Wanapitei lake and river, on the east, to Onaping and Worthington stations on the west. On the north it may be considered as embracing the recently discovered iron deposits in Hutton township, while southward the commencement of the Laurentian gneiss is believed to limit important mineral discoveries in that direction.

The town of Sudbury is a creation of the Canadian Pacific railway, coming into existence at the time of its construction in 1882, and increasing in importance by reason of its being chosen as the junction point for the branch line to Sault Ste. Marie. It is distant on the main or transcontinental line of this railway 442·7 miles from

Montreal, and 322·4 miles from Ottawa, the capital of the Dominion of Canada.

The area in which workable deposits of nickel and copper are now known to occur extends from the southeast corner of Snider township (Evans mine), northwest to the central part of the township of Levack, a distance of about 20 miles; in a northeasterly direction it reaches from the township of Drury to Wanapitei lake, a distance of about 40 miles. The mines which have actually produced ore for smelting or shipping purposes are, with the exception of the Worthington mine, all connected with that portion of the main mass or belt of norite which stretches from the old Inez or Chicago mine, in the township of Drury, to the Blezard mine, a distance of about 26 miles.

The area contained in the two accompanying map-sheets (Victoria Mines and Sudbury), and comprising portions of the district of Algoma and Nipissing, has all been subdivided into townships and lots of the more recent form adopted by the Crown Lands Department of Ontario. With few exceptions each of these townships measures six miles square, the area thus embraced being thirty-six square miles. Each township is divided into six concessions by east and west lines run astronomically, which are designated by the Roman numerals, the order of numbering being from south to north; while the concessions themselves are divided into twelve lots, by true north and south lines, which carry the ordinary Arabic figures, numbered from east to west. Each lot, therefore, measures one mile from north to south, and half a mile from east to west, thus containing an area of 320 acres. Only every alternate lot line is cut out through the woods, the intervening boundary being marked by posts on the concession lines. The lines are all supposed to be run astronomically, although in some cases, no allowance having been made for the convergence of meridians, considerable error and confusion have resulted. Sometimes the surveys of these townships have not been done as carefully or accurately as might be desired, and in more than one instance, two or even more approximately parallel lines were found, within short distances of one another, evidently intended for a single boundary, each connecting with separate posts designed to mark the same point. Over the larger part of the district repeated forest fires have destroyed all traces of many of these lines, and the limiting posts, except where an occasional one happened to be located in a swamp, have been burnt, so that it is usually exceedingly difficult, and sometimes impossible, to locate these original boundaries.

The general character of the country may, perhaps, be best described as that of an uneven or undulating rocky plain, with a gentle slope towards the south and southwest. In detail the surface of the plain is far from uniform, consisting of a rapid succession of more or less parallel and disconnected rocky ridges, with a prevailing northeast and southwest trend, the intervening valleys being usually occupied by swamps, lakes or river courses. The average general elevation of the district, as a whole, varies from 800 to 1,100 feet above the sea. The present topography has been the result of prolonged denudation and erosion, assisted to a considerable extent by subsequent glacial action, which removed the softer decomposed material from the higher levels to be deposited elsewhere in the neighbouring valleys or in areas considerably removed to the southwest. The scouring action of the vast glacier is everywhere apparent in the smooth well-rounded hills, while in most cases the exposed rock surfaces still preserve the glacial grooves and striæ. Although the country is exceedingly rocky and uneven there are no very prominent hill features, the highest seldom attaining a greater altitude than 150 feet above the neighbouring valleys, while elevations of 25 to 100 feet are far more common. The highest land in the district comprises a strip varying in width from 3 to 5 miles, and extending in a northeasterly direction from Denison to Garson townships, a distance of over 30 miles. This is underlaid for the most part by the nickel-bearing and associated eruptives, although some areas of highly altered quartzites contribute to this unusual elevation. One of the highest hills in this rocky belt is situated immediately south of the Elsie mine. Barometrical observation correlated with the known elevation at the intersection of the Elsie Mine branch with the M. & N. S. railway show this to have an altitude of 1,120 feet above the sea. Starting from Sudbury, which has an elevation of 850 feet, the Canadian Pacific railway ascends a series of steep grades for a distance of 3½ miles before the summit is reached at an altitude of 992 feet; while an equal distance farther, at Azilda station, this elevation is decreased to 881 feet above the sea. The Manitoulin and North Shore Railway Company, on the other hand, have built a portion of this road a little over twelve miles in length, and have located it to Victoria Mines and beyond, the line running through this hilly district for the whole distance. Starting from Sudbury, which, as stated, has an elevation of 850 feet, the grade rises to 919 feet at Clarabelle junction, and farther to 959 feet at Elsie junction. The summit is reached about 8 miles west of Sudbury, where the level of the rail is 986 feet, falling again to 965 feet above the sea, at the end of the profile 12·7 miles from Sudbury, close to the Gertrude mine. To the northwest of this hilly tract the land becomes tolerably level, forming a plain with an average elevation of nearly 880 feet above the sea. This flat belt of country has a general width of about six miles, and stretches from the vicinity of Vermilion lake, in Fairbank township, almost to Wanapitei lake, a distance of over 30 miles. The whole of this area is evidently underlaid by the slates and feldspathic sandstones coloured provisionally as of possible Cambrian age, but this rocky floor is largely concealed by a thick mantle of drift, through which protrude occasional low, rounded hummocks, which alone give evidence of the underlying material.

This drift is composed of a well stratified grey clay, unencumbered for the most part by boulders, and is seemingly well adapted for all purposes of agriculture. Roads have been opened and large clearances made over most of this level district, the various barns and buildings erected giving strong evidence of the prosperity of this farming community.

To the south, and southeast of the hilly stretch already mentioned, a somewhat irregular shaped and comparatively narrow valley extends from the vicinity of the Worthington mine almost to Wanapitei lake, where it connects to the north and west with the extensive plain just described. The continuity of this comparatively level tract of country is broken at certain intervals, as for instance near the crossing of the Whitefish river, but the whole flat may be considered as belonging to one valley, with a gentle though perceptible slope towards the southwest. In the township of McKim this flat has an average general elevation of about 845 feet above the sea. From Sudbury, in a southwesterly direction, this comparatively level belt has been utilized in the location of the 'Sault Branch' of the Canadian Pacific railway, while, in addition, advantage has been taken of the even surface in erecting most of the buildings included in the towns of Sudbury and Copper Cliff. In the township of McKim the surface of this flat is sometimes broken by small rocky hills, and the considerable areas that are available have been cleared and are now under cultivation with gratifying results, especially during those years when the roasting of the ores at the mines is not proceeding too briskly.

Throughout McKim, and the area to the southwest of this township, the soil is a fine silty clay, well stratified; but to the northwest, in the township of Garson and beyond the limits of the Sudbury sheet, in the township of Falconbridge, this is replaced by a coarse yellow sand, with gravel in certain places, the whole forming a light and rather poor soil, although some portions of it are now being used for farming purposes.

To the east and southeast of Sudbury the district is, for the most part, exceedingly rough and hilly, this area being characterized by the presence of quartzite, with large and irregular intrusive masses of norite and diorite, and only occasional limited flats are available for agriculture.

Perhaps one of the most interesting physical features presented by this district is the narrow valley formed by the weathering of the large diabase dike, near the Murray mine. This dike, which is about 150 feet wide at this point, and intruded through a mass of granite, has been decomposed and considerably eroded, leaving a valley the whole width of the dike, with perpendicular walls of granite. This very conspicuous feature in the landscape has been used in locating the wagon road between Sudbury and Azilda (formerly Rayside).

The influence exerted by the underlying rock on the general contour of the ground is everywhere well exemplified throughout this district. The harder igneous and quartzite rocks, owing to their greater resistance to processes of weathering and erosion, form the higher ridges, while the more fragile slates, sandstones and schists make up most of the intervening lower ground, occupied chiefly by the river valleys, swamps and lake basins. The area covered by the main mass or belt of norite is likewise one of low relief, in contrast with the other igneous rocks, with very small gently rounded hills, this variety of rock evidently offering no very effectual resistance to decomposition. The district, as a whole, is not as abundantly supplied with lakes as many other areas of similar Archæan rocks, but several fairly large and beautiful lakes occur, and nearly all are supplied with good clear water. The shores and islands of Ramsay or Lost lake are occupied by the summer residences of many of the inhabitants of Sudbury, while its pure clear water is used to supply the large water tank, erected for the water works on one of the rocky hills east of the town. The highest lake in the area is Garson lake, which is 923 feet above the sea; while the lowest is McCharles lake, an expansion of the Vermilion river, which has an altitude above the sea of 760 feet.

The drainage of this district is effected through three important and well known streams, the Wanapitei, Spanish and Vermilion rivers, the whole of the water eventually reaching Georgian bay and Lake Huron through these channels. The Vermilion river with its tributaries, the Whitefish branch, Levey river, and Whitson and Fairbank creeks, empties the water of nearly the whole of the area included in the two map-sheets. The Vermilion river is itself a branch of the Spanish river, joining this stream near the boundary between Merritt and Foster townships, about ten miles southeast of the corner of the Victoria mines map. A portion of the Spanish river, known as the 'Great Bend,' crosses the corner of this map-sheet, receiving in this distance the whole of the drainage of the township of Drury, and the western part of Denison township. The branches of the Wanapitei river are limited to the eastern parts of Garson and Neelon townships.

The whole area was once covered with a dense forest, but repeated fires have destroyed nearly the whole of this original growth, and even the tall rampikes, which often alone remain as the silent witnesses of the havoc wrought by the fire fiend, have themselves been gradually cut down to aid in kindling the heaps of roasted ore. Occasional small areas, as for instance in the northern part of Garson and the western part of Snider and Creighton townships, are still covered by green bush, but the lumberman's axe is quickly clearing out all the valuable timber that remains, while the constant demand for cordwood, as fuel for the roast heaps, will still further limit the forest area. Hardwood is scarce, and can only be found in valleys, chiefly in the vicinity of certain streams. Occasional dwarf oaks were noticed in some of the hollows between the higher ridges. The second growth usually consists of poplar and birch, these small trees being so closely packed together in some of the valleys as to form almost impenetrable thickets.

The district, as a whole, cannot be said to be suitable for agriculture, and must rely for its ultimate importance on the development of its mineral resources. The proximity of the mines furnishes a good market, so that every flat is being utilized for purposes of farming.

Geology.

The rocks of the Sudbury mining district, arranged in the probable order of their geological age, may be stated as follows, in ascending order.

1. *Lower Huronian.* No rocks of this age are at present known in the nickel bearing area, but this period is represented, in part, by the banded siliceous magnetites and associated rocks of the townships of Hutton and Wissner.

2. *Upper Huronian.* (*A*) Diorites, hornblende-porphyrites and green schists. (*B*) Conglomerates, greywackes and quartzites (*C*) norite and diorite (Worthington mine belt, and areas southeast of Evans mine and east of Sudbury).

3. *Laurentian.* Granite and diorite-gneiss near Wanapitei station.

4. *Upper Huronian?* Tuffs, feldspathic sandstones and slates classified provisionally on previous geological maps as of Cambrian age.

5. *Post Huronian.* *A*. Granites. *B*. Nickel bearing eruptive of the main belt (quartz-hypersthene-gabbro or norite, diorite, with their peculiar differentiation product, micropegmatite). *C*. Dikes of olivine diabase.

6. *Pleistocene.* Clays and sands.

The geological history of the nickel mining area proper, or that portion of the Sudbury district which is included in the accompanying map-sheets, began in very ancient times, and most of the rocks now exposed are regarded as representative of what is known as the Huronian period, being thus the oldest with which geologists are at present familiar. The detailed examination and study of these rocks have furnished abundant evidence of the almost unexampled volcanic activity then prevailing, caused largely, no doubt, by the instability of the earth's crust at this early period of its history. These rocks are essentially of pyroclastic origin, consisting mainly of tuffs of both acid and basic types, intimately associated with more or less altered basic eruptives, some of which still retain much of their original massive character, although by far the larger proportion have undergone such profound deformation and metamorphism that it is exceedingly difficult, if not impossible, even with the assistance of the microscope, to make any very definite or accurate statement in regard to their original composition and structure. Some of these eruptives are, however, probably of laccolithic origin and intruded along the planes of bedding of the enclosing clastic rocks, while many of the porphyrites and obscurely amygdaloidal forms doubtless represent surface flows of lava which have been very much altered and decomposed.

With the establishment of conditions of more stable equilibrium came a time when the higher elevations were being subjected to the usual processes of degradation and erosion, with the transportation of the material thus detached to be deposited at the lower levels, forming the conglomerates, feldspathic sandstones and quartzites included in the above table as Upper Huronian. Even this period of comparative quiet was probably interrupted at intervals by a return of the volcanic activity, and some of the breccia-like material and certain of the interbedded greywackes may be the direct results of explosive action. Subsequent to the formation of these rocks the huge batholiths of granite and diorite-gneiss classified as Laurention, and occurring in the vicinity of Wanapitei station, were intruded into the highest or quartzite member of the Upper Huronian. Later than these quartzites, and possibly also later than the Laurentian gneiss, certain masses of notrite and diorite, among which may be mentioned the belt on which the Worthington mine is located, were intruded. This Worthington mine band of norite, as may be seen by a reference to the map, extends across the southern part of the township of Denison, forming a conspicuous range of hills a short distance south of the Canadian Pacific railway. The band of similar igneous material which forms the high lands to the south of McCharles lake is of the same age, as also its probable continuation in the large belt of norite and diorite, which crosses the country to the southeast of the Evans mine. This same band of intrusive rock continues with unbroken continuity northeast, forming a considerable area of exceedingly rough country east of Sudbury, and north of the Canadian Pacific railway, besides covering a considerable portion of the northern and central parts of Neelon township.

The age of the tuffs, feldspathic sandstones and slates hitherto classified provisionally as of Cambrian age, and so coloured on all previous geological maps, is still a matter of considerable doubt, and much more detailed work and critical examination of the area characterized by the presence of these rocks will be necessary before this can be satisfactorily settled. They apparently form a synclinal basin, resting against the micropegmatite phase of the nickel bearing eruptive, and a study of several of the localities where the junction between these rocks is exposed lends some support to the belief that the micropegmatite is intrusive through the tuff or breccia. On the other hand, it seems reasonable to suppose that all of these rocks are very intimately associated in regard to their time and manner of genesis.

The granites, usually referred to as 'younger,' are decidedly so, in reference to the older diorites, porphyrites and green schists, and a rock which may be called a breccia, formed by an exceedingly intricate intrusion of dikes and masses of granite material through these basic rocks, covers considerable areas throughout this district; while even the main mass of the granite batholith frequently contains embedded fragments and masses of all sizes and shapes of these older greenstones.

The nickel bearing eruptive, which in its fresh condition is now referred to as a quartz-hypersthene-gabbro or norite, is decidely later than, and intrusive through, the green schists and associated diorites. The relations between the so-called 'younger' granite is much more complex and anomalous. For the most part, the nickel bearing eruptive has cooled against the granite, as may be seen at the junction between these two rocks, on the west side of the large pit known as the No. 2 mine at Copper Cliff. Here the norite is distinctly finer in grain at the immediate point of contact, this rock growing visibly coarser farther away from the line of junction. This cooling of the norite against the granite, and the production of a finer-grained or chilled selvage, is especially well seen in the vicinity of the openings made by the Vivians on lot 9, concession VI, of McKim township. On the other hand, in some localities, certain dikes or apophyses of the granite seem to penetrate the norite, as may be noticed along the line of junction to the northwest of No. 2 mine, at Copper Cliff; while the intrusive nature of the granite, and its apparently later age in relation to the norite, is quite marked to the north of Clarabelle lake, where the line of junction between the two rocks is well exposed for a considerable distance. Besides, near the Creighton mine, the granite becomes decidedly more basic in the vicinity of the norite, and a certain zone or belt is formed by the commingling of the material of both rocks, as a result of actual fusion. It has been suggested that the granite and norite may have been differentiates of the same magma, but a more reasonable explanation would seem to be that their periods of intrusion were so closely synchronous that they overlapped in their time of crystallization, and that the later secretions from the slower cooling granite magma forced or ate their way into the norite in certain places.

The olivine-diabase dikes cut through, and are, therefore, later than all the rocks with which they have been noticed in contact. Their mineralogical composition is essentially the same as the dikes of diabase-porphyrite in the Lake Superior district, which latter have been regarded as the channels by which the Keweenawan lavas reached the surface.

(2.) Upper Huronian.

(A.) greenstone schists.

It has been the general practice in previous reports of this and other Archæan areas to employ the somewhat vague and indefinite term 'greenstone,' the common field name for certain basic eruptive rocks, often more or less altered and deformed. In the present report this term has been retained as the most appropriate and convenient designation for certain very ancient basic intrusives, presenting every possible phase of metamorphism and deformation. Under the general heading, 'greenstone schists,' are included several varieties of diorite, porphyrite, hornblende and chlorite schists. They are undoubtedly the oldest rocks with which we have at present any acquaintance in the district. Their usual occurrence in intimate association with the more massive and uniform norite, in addition to their general lithological appearance and behaviour, especially the more massive types, were the main reasons for grouping these rocks together, under the same colour designation, on all the earlier geological maps. In these first examinations such rocks were regarded as the sheared and altered representatives of the more massive norites, the latter, by some fortunate circumstance or series of circumstances, having escaped this extreme of deformation and metamorphism. Later examinations have, however, revealed the fact, that in most cases at least, these more or less foliated and schistose basic eruptive rocks are distinctly older in age, and were upturned, faulted, folded and considerably metamorphosed at some time prior to the intrusion of the nickel bearing eruptive proper. Careful and detailed work never fails to reveal the presence of a distinct line of separation between these two classes of igneous rocks, and the importance of accurately tracing out and mapping such a boundary, from an economic point of view, is especially emphasized, when it is remembered that all the deposits of nickel and copper ores, which are commercially valuable, are located either in the immediate neighbourhood, or at various points directly on the line of junction between the norite and the associated rocks.

The least altered representatives of these older diorites, or more massive varieties of the older greenstones, can with difficulty be distinguished from the prevailing type of diorite (altered norite), with which the nickel and copper deposits occur, and it is impossible to resist the conclusion that both rocks have originated from precisely similar types. The difference in age, however, is quite evident from their field relations, and although both pyrrhotite and chalcopyrite occur in these earlier basic rocks, no deposits of economic importance have been found in association with them at any great distance from the line of junction with the younger norite or diorite.

Most of the hand specimens examined of the more massive types of these older rocks are considerably finer-grained than the neighbouring norite, and, in contrast to this rock, are decidedly greenish rather than greyish or blackish in colour. Most of the outcrops may be referred to as 'gabbro-diorite,' a name proposed by the late Prof. G. H. Williams for a diorite which gives unmistakeable evidence in the hornblende of its derivation from pyroxene, originally present. Some exposures exhibit the ophitic or interlacing structure characteristic of diabase, which is often discernible either to the unaided eye, or with the assistance of an ordinary pocket lens, and the rock in which the structure is developed would be referred to as uralitic diabase.

Mineralogically, as represented by the thin sections examined under the microscope, the rock is now composed essentially of plagioclase and hornblende, and no portion of the original pyroxene has yet been detected. The plagioclase, in all cases where the rock is sufficiently fresh for identification, is labradorite, and in those specimens which have suffered least from metamorphism this mineral occasionally has a pale brownish tint, the colouring matter (presumably very finely disseminated ilmenite), being rather unevenly distributed through the various individuals, with cloud-like effect. Pressure and advancing decomposition, however, seem to quickly destroy or remove all traces of this colouring matter, so that, with few exceptions, the feldspar is nearly, if not quite colourless. As a rule, the plagioclase has undergone more or less advanced saussuritization, but some individuals are still sufficiently fresh to permit of their recognition by means of the extinction angles. All stages in this characteristic alteration of the basic plagioclase are represented in the specimens collected and examined, but this has been so fully described in previous publications that only a brief mention is necessary in this connexion. The first step in the decomposition of the original feldspar consists in the development of minute scales of sericite, and fine needle-like forms of epidote and zoisite in the midst of the plagioclase substance. Another, and very frequent form of development of these secondary minerals, consists of grape-like bunches of finely granular saussuritic material, chiefly zoisite or epidote, whose coalescence ultimately produces a single larger individual, or aggregate of several individuals of these minerals. One of the more advanced stages in this process of decomposition of the feldspar consists in the complete obliteration of the twinning lamellæ, and the replacement, either wholly or in part, of the plagioclase substance, by a brilliantly polarizing aggregate, made up chiefly of sericite, epidote and zoisite. In occasional instances the place of the feldspar is taken by a colourless or pale yellowish saussurite, which polarizes in dull bluish tints. This substance is usually so fine-grained that it cannot with certainty be resolved into its component minerals, even with the assistance of the higher powers of the microscope. Some of the coarser portions of this substance were examined rather critically, with the result that zoisite, sericite, a little calcite and a secondary plagioclase, possibly albite, were recognized as contributing to the aggregate. Still another form of alteration of the original feldspar, and one often accompanying the more usual saussuritization, consists in the replacement of part of the original feldspar by a fine interlocking mosaic of a clear, sharply extinguishing, secondary feldspar (albite) and quartz.

The hornblende is, as a rule, the usual deep green, strongly pleochroic, compact variety, occurring in long, imperfectly developed prismatic forms. Occasionally the fibrous or actinolitic variety is represented, much paler in colour, and with less pronounced pleochroism. Many of the individuals of this mineral show the pale coloured, more or less non-pleochroic interiors, with deep coloured, much more compact, and strongly absorptive borders characteristic of uralite. Portions of occasional crystals show a brownish colour, but even these have a decided greenish tinge. Biotite is almost invariably present, and usually in large amount. It is of the usual deep brown colour, showing strong differences in the absorption of light when rotated between crossed nicols. It occurs in plates and scales, frequently embedded in, and sometimes forming intricate parallel intergrowths with the hornblende. It has often undergone considerable 'bleaching,' and is then somewhat paler in colour than usual, besides showing brilliant chromatic polarization between crossed nicols. In spite of the elimination of a considerable portion of the iron the pleochroism, as stated, is still very pronounced. It often contains irregular grains of magnetite. Both the hornblende and biotite show frequent decomposition to chlorite. 'Pleochroic halos,' surrounding embedded small grains or crystals, chiefly of sphene, are frequent in both the hornblende and biotite, as well as in the chlorite derived from them. Comparatively large and sharply defined crystals of epidote and zoisite occur, some of which may be of primary origin, although by far the larger proportion are undoubtedly the secondary products of decomposition. Quartz is almost invariably present, occasionally forming the characteristic granophyric intergrowth with the feldspar. In most cases it is not of secondary origin, but an integral part of the same magma out of which the other minerals have been formed. It was as usual the last mineral to form, filling up the irregular interspaces left by the crystallization of the other constituents. Ilmenite and highly titaniferous magnetite are the prevailing iron ores, and these are present often in comparatively large amount. Most of the individuals are surrounded by opaque greyish leucoxene, or the more normal sphene, resulting from the alteration of the titaniferous iron ore. Apatite is usually present in small amount, occurring in the characteristic long, acicular, prismatic forms, which pierce all the other constituents of the rock. Pyrrhotite, chalcopyrite and pyrite frequently occur disseminated through the rock, and under the microscope are seen to form curious irregular skeleton or sponge-like masses, intimately associated with, and frequently embedded in the coloured constituents.

These diorites occur in all stages of decomposition, while still retaining much of their original massive character. A type illustrative of perhaps the extreme of this alteration is well represented by a hand specimen obtained from the tunnel in 'Lake Hill,' lot 8, con.

IV, of Denison. This rock is a fine-grained, comparatively light greenish-grey, diabasic rock, with occasional fine disseminations of pyrrhotite and chalcopyrite. The thin section shows that all of the hornblende and part of the biotite have been altered into green chlorite, which retains much of the strong pleochroism characteristic of the original minerals from which it has been derived. The ilmenite has been almost wholly converted to sphene, which occurs in irregular grains and crystals. Calcite is very abundant, and portions of the slide are made up of a rather coarse mosaic of quartz and calcite, with a smaller proportion of chlorite. As a rule, these old diorites are comparatively uniform in grain, but porphyritic varieties occur, and a good example of this phase was collected from certain small rounded hummocks, on the west side of the upper or new roast yard of the Victoria mines, (N. $\frac{1}{2}$ lot 8, con. III, Denison). The hand specimen shows a comparatively coarse-grained rock, made up of indefinite or irregular phenocrysts of dark green, almost black hornblende, embedded in a proportionately smaller amount of a comparatively fine-grained matrix, which is rather paler in colour. The microscope shows the rock to be a porphyritic diorite, made up very largely of a green, feebly pleochroic hornblende. Much of the hornblende is compact, but in the finer-grained portions of the rock, as well as in the terminations of the larger crystals, the mineral shows a marked tendency to assume the actinolite habit. The interspaces between the larger porphyritic individuals are made up of saussuritized plagioclase, actinolite and ilmenite, the latter mineral in various stages of alteration to leucoxene. Occasional small scales of biotite may be noticed embedded in the hornblende.

Another closely related rock is that which is usually referred to as 'hornblende-porphyrite.' This type of rock is perhaps best illustrated by outcrops occurring to the southeast of the Elsie mine, while the steep and prominent hill southeast of the office at the Murray mine, is almost wholly made up of this material. The groundmass is much finer in grain than in the porphyritic diorite just described, but the phenocrysts are usually considerably larger and more conspicuous, their deep green, almost black colour, with glistening cleavage planes, contrasting well with the fine-grained and lighter coloured matrix made up largely of hypersthene with some feldspar. Still another closely related form, and one which may be included in the general class of the older and more massive greenstones, may perhaps be best described as a 'diorite-porphyrite.' The best examples of this type of rock were obtained from exposures outcropping a little north of the boundary between Graham and Creighton townships, on lot 2, con. I, of Creighton township. The hand specimen shows a dark-green, rather schistose, dioritic rock, with ill-defined phenocrysts of plagioclase, some portions of which are of a paler yellowish-green colour, while other parts of the same crystal are reddish. Under the microscope the thin section shows that these large irregular phenocrysts are labradorite, which have undergone more or less advanced alteration to saussurite or huronite, with the development of zoisite, epidote and sericite. The reddish portions of the crystals are comparatively unaltered and still show the twinning lamellæ. The finer interstitial matter is made up essentially of green hornblende and plagioclase. Some of these individuals show the pale interiors and comparatively dark-green borders usually considered as characteristic of uralite. Most of the plagioclase has undergone more or less advanced saussuritization. The iron ore present is mainly ilmenite, for it may be seen undergoing alteration to leucoxene. A little quartz is present, and also an occasional scale of biotite.

Very frequently these more massive types pass into foliated schistose varieties, the structures being the direct result of pressure and stretching, and all gradations may frequently be observed in the same rock exposure, from the massive gabbro-diorite, through diorite schist, hornblende schist or amphibolite, to actinolite and chlorite schist. The prevailing type of hornblende schist or amphibolite is a dark-green to almost black, usually glistening and very fissile rock. It is made up largely of slender prisms of the common green hornblende, usually compact and strongly pleochroic, but sometimes actinolitic, a varying but usually small amount of plagioclase and quartz occupying interspaces between the rudely parallel individuals. In the less altered varieties the original plagioclase still remains, although usually more or less saussuritized, but some specimens examined are seen to have undergone more or less complete recrystallization, with the formation of an interlocking mosaic of water-clear, usually unstriated plagioclase (albite?) and quartz. Biotite is almost invariably present, and the iron ore is sometimes ilmenite, or highly titaniferous magnetite, the grains of this mineral being bordered with sphene. In other instances the iron ore is simply magnetite, showing no traces of alteration and this mineral is often present in large quantity. Pyrrhotite, chalcopyrite and pyrite are sometimes disseminated through the rock in small grains, and in the vicinity of the ore-bodies these sulphides are often abundantly present in this type of rock. Some exposures of these rocks are made up almost entirely of hornblende. The thin section of a specimen secured from Cryderman mine, (lot 5, con. III, Garson) showed this rock to be made up of hornblende individuals closely compacted together, with no intervening feldspar or quartz. Magnetite is abundant, while pyrrhotite and chalcopyrite are thickly disseminated through the rock. Some phases of these hornblende schists are sometimes so badly decomposed that only occasional cores of the hornblende crystals have survived, the remainder having been converted into chlorite. The plagioclase and quartz present in these rocks are often indistinguishable from one another, the former being the clear, often unstriated variety (albite), so characteristic of these recrystallized eruptives. Biotite is present in much smaller amount, and has likewise contributed by its alteration to the formation of the abundant chlorite. Epidote and calcite are also present in comparatively large amount, as secondary products of decomposition. Magnetite is plentiful, and much of it is undoubtedly of secondary origin. These rocks are usually much paler in colour than the prevailing and less decomposed varieties of amphibolite.

In certain localities these hornblende schists were noticed to contain numerous small, irregularly oval, light-coloured patches or 'augen,' sometimes made up almost entirely of plagioclase, or this mineral in association with an equal or even greater quantity of quartz, while in certain instances quartz alone is present. These are of various sizes and shapes, but they are usually less than a quarter of an inch in diameter, and most of them are about the size of an ordinary pea. In certain instances some of the larger of these areas seemed to be made up of a single imperfect phenocryst of plagioclase, but a study of the slides usually shows a mosaic made of several distinct interlocking grains of this mineral, together with a varying amount of quartz. The rock, at first sight, suggests an amygdaloid, with the amygdules or vesicles filled with this quartzo-feldspathic material, but a more reasonable explanation suggests their probable origin as small, more or less continuous veins of pegmatite which have become thus deformed and separated as a result of stretching. The structure is of rather frequent occurrence and characteristic of comparatively large areas of the amphibolite. Similar rocks have been noticed by Dr. Coleman as occurring in the vicinity of the Frood mine, while in the central part of the township of Graham the writer has collected several specimens from the N. ½ lot 8, con. III, and the N. ½ lot 1, con. IV, of this township. The matrix in which these small eye-like forms are developed shows a fine-grained hornblende schist made up, in great part, of compact, dark-green, strongly pleochroic hornblende, together with a little biotite. In the specimen from the N. ½ lot 1, con. IV, of Graham, the quartz and feldspar of many of the 'augen' contain small scattered individuals of hornblende, zoisite and biotite.

Another type of rock, which was noticed at two widely separated localities, intimately associated with these amphibolites, is a dark-grey, almost black, faintly glistening schistose rock. The thin section of a specimen obtained near the openings on lot 12, con. IV, of Denison, shows a fine-grained aggregate of pale-coloured or 'bleached' biotite, with a much smaller amount of plagioclase. Small grains of sphene are abundant, and also irregular fragments of calcite.

Another variety of the same rock is represented by a specimen obtained near the Century Copper mine, on the N. ½ lot 4, con. IV, of Graham. It contains frequent disseminations of pyrrhotite, pyrite and chalcopyrite, and in addition to the plagioclase contains a considerable amount of quartz. The biotite, which is in fairly large plates, is 'bleached' with frequent pleochroic halos, surrounding certain of the smaller inclusions, which are abundant, and include sphene, epidote and zoisite.

Occasionally these amphibolites contain garnet, which is sometimes abundant, and often in large, ill-defined or rounded crystals. The most striking example of such a rock is, doubtless, that occurring in the vicinity of the Vermillion mine, (lots 5 and 6, con. IV, of Denison). The matrix shows the prevailing fine-grained, dark-green schist, in which rounded crystals of reddish garnet, sometimes two inches in diameter, are developed. The matrix is made up principally of hornblende and quartz. The garnet is quite normal, but is much cracked and slightly seamed with green chlorite, which has resulted from its incipient alteration. It was also noticed to contain inclusions of magnetite and quartz.

There can be little doubt in regard to the origin of most of these older greenstones that they represent greatly decomposed, sheared, and, at times, completely recrystallized, basic eruptives, but there is still considerable doubt regarding the exact conditions attending the genesis of certain other types of rocks, which are intimately associated with, and usually included in these greenstones. Some of these show, though somewhat indistinctly, the ellipsoidal and amygdaloidal structures characteristic of lava flows, while others, again, are almost certainly of a pyroclastic nature, representing consolidated beds of volcanic ashes and fine agglomerates, but all of these have been so greatly squeezed and stretched that their precise identification is extremely difficult, if not impossible. Some portions of the sedimentary rocks, chiefly quartzites and greywackes, are included in these areas of greenstones. In some instances these clastic rocks, which have thus been caught up in the greenstone, are sufficiently large to permit of being separated on the map, but, for the most part, they are comparatively small, and have been included under the same colour as the greenstone. All of these clastic rocks are greatly metamorphosed. The tuffs or greywackes are now made up chiefly of clear feldspar, with a smaller proportion of quartz, the former mineral being largely altered to sericite; biotite, chlorite and magnetite or ilmenite are the most abundant minerals represented. Often decrystallization has been so advanced that no traces of their detrital origin remain. The quartzites are of the usual feldspathic variety, the component grains only occasionally revealing traces of water action, the structure, for the most part, being eminently interlocking.

(2.) Upper Huronian.

B. CONGLOMERATES, FELDSPATHIC SANDSTONES AND QUARTZITES.

Although a large proportion of the rocks included as Huronian in the Sudbury district are the direct result of igneous action, considerable areas are underlaid by others of undoubtedly sedimentary origin. While, however, the various types of these rocks have been studied in considerable detail, so that their precise mineralogical composition is well understood, their stratigraphical position has not been determined as satisfactorily as might be desired, as only a comparatively limited time could be spared from the work of examining and delimiting the more important eruptives directly associated with the ore bodies. The geological succession, therefore, advocated in this report, is not based on an extended or critical study of the field relations of these rocks, and much more exhaustive work will be necessary before a final and authoritative utterance is possible on this point. Some difficulties which presented themselves, during even the preliminary investigations undertaken by the writer, may be mentioned briefly. In the first place all the rocks of the district have been greatly disturbed, so that the originally horizontal strata are now tilted at very high angles, in some instances having assumed a vertical attitude, and, occasionally, having even been overturned as a result of the mechanical stresses to which they have been subjected. In some cases, and over extended areas, the rocks have been so metamorphosed that the planes of original sedimentation are more or less completely masked, or even destroyed altogether, thus rendering it very difficult, if not impossible, to interpret the true structure or succession. In addition, the situation is further complicated, and a satisfactory explanation delayed, by reason of the frequent development of certain secondary structures due to intense and prolonged pressure and stretching. The foliated, schistose or slaty structures, thus induced, are frequently mistaken for bedding planes, although usually forming considerable angles with them. Besides, the continuity of the areas of the clastic rocks is frequently broken by the intrusion of irregular masses of igneous material, which not only greatly disturbed and obscured the original order of deposition, but divide these sedimentaries into a number of separate basins, whose satisfactory correlation can only be unravelled by much more detailed study than the present opportunity afforded the writer. At this stage, therefore, the succession favoured in this report is not offered without a certain degree of hesitation, although it is without doubt a much more complete and satisfactory classification than any which has yet been attempted. With the exception of one or two minor points it differs in no essential particular from the scheme offered by Dr. Coleman in his last report, (1) and we both agree in advancing the opinion, that the intrusion of the nickel bearing norite took place at a much later date than formerly supposed. It is confidently expected, however, that Dr. Coleman, as a result of the later work he is now conducting in the district, will decide many of the questions which are still a matter of opinion and conjecture, and the appearance of his monograph is accordingly awaited, with the expectation that this question of succession, especially, will receive full and satisfactory treatment.

The oldest clastic rocks exposed in the vicinity of Sudbury are certain feldspathic sandstones or greywackes, frequently interbedded with, and passing by insensible gradations into feldspathic quartzites or arkoses, the latter, for the most part, being the later rocks, and usually forming the summit of the series. These rocks are evidently closely related, the main point of difference noticed consisting in the relatively coarse grain and large amount of quartz in the quartzites, with less of the finer-grained interstitial material, this being made up, for the most part, of the lighter coloured decomposition product sericite, while in the greywacke the texture is finer, and feldspar, not quartz, is the predominant constituent. Chlorite, with innumerable fine, disseminated particles of opaque matter, gives the prevailing dark colour to the rock. The quartzites, for the most part, occur in thick, massive beds, which are very uniform in mineralogical composition, while the greywackes are much more distinctly and evenly stratified, and certain shales and slates exposed in the district are evidently thinly bedded varieties of this rock. All intermediate stages, both in composition and structure, may be noticed between these two types of rock, which, at the two extremes, are quite distinct and recognizable.

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, p. 298.

Comparatively large areas are characterized by the prevalence of one or other of these rocks.

Some of the greywackes are evidently of the nature of muddy sediments deposited in water, as a result of ordinary conditions of degradation and deposition, but tuffs constitute, by far, the larger part, representing the consolidation of what was originally volcanic ashes, being one of the results of the explosive action to which is due the presence, at the surface, of the great belts of greenstone. These have, in most cases, been sorted and re-arranged by the action of water, but, in other instances, little or no trace of rounding action can be detected in the component grains, even in those types which have suffered little or no alteration. These rocks are usually of a dark-grey, purplish-brown, or greenish-grey colour. They are often evenly and very distinctly banded, in varying shades of grey. Jointing is frequent and also slaty cleavage. They are often faulted and shattered, and in the vicinity of the various greenstone masses are penetrated and altered by irregular tongues and masses of the basic igneous material. They are frequently porphyritic, and usually the phenocrysts are small, very thickly disseminated, and of a very pale-greyish or whitish colour. For this reason the rock has been referred to, in the field, as 'rice rock.' These phenocrysts were probably andalusite or staurolite, but the skeleton-forms are now occupied by a confused aggregate of minute sericite scales and quartz. Other exposures show small yellowish-brown spots made up of rutile, while others again exhibit irregular phenocrysts of hornblende, now wholly replaced by chlorite. Thin sections, examined under the microscope, reveal a rock which has undergone rather extensive decomposition. It is usually made up very largely of feldspar, with a smaller proportion of quartz, in small, angular or slightly rounded fragments. These are surrounded by a net-work of sericite and chlorite scales, together with a considerable amount of opaque iron ore. The larger individuals, at least, have evidently been ilmenite, but are now almost completely altered to leucoxene. The darker bands are made up of more thickly disseminated, dust-like particles of iron ore, much of which at least is ilmenite. In the vicinity of the various eruptive masses, as well as in those masses which have been caught up in the greenstone, these rocks are very much altered, the various types having been described as mica schists, felsites and phyllites. The rocks referred to as quartzites are massive, though usually distinctly stratified, of a pale-grey, reddish, yellowish-grey, or greenish-grey colour. They are intimately associated and often interbedded with the tuffs or greywackes, so that it is frequently impossible to separate the two for purposes of mapping. Under the microscope the thin section exhibits a rock made up chiefly of quartz, with a somewhat smaller proportion of feldspar, most of which is unstriated, and, therefore, presumably orthoclase. Occasional grains of microline were noticed, showing the various stages in the development of the characteristic fine, cross-hatched, twinning structure. Much of the feldspar is decomposed into a hydrous form of muscovite (sericite), occurring in irregular, pale-yellowish or colourless scales and plates, which, together with fragments of undecomposed feldspar, make up a groundmass, in which the larger individuals of quartz, and more rarely of feldspar, are embedded.

The structure of the rock is for the most part interlocking, but some specimens show distinctly clastic structure, while, in most, the resemblance to well authenticated, recrystallized clastics is such as can hardly be mistaken.

A little over a mile northwest of Sudbury the Canadian Pacific railway crosses a belt of very highly altered feldspathic quartzite, the outcrops of this rock forming a series of comparatively high and conspicuous ridges. This band averages about half a mile in width, and extends with unbroken continuity from the vicinity of the Frood mine to Copper Cliff. Here, denudation has removed a considerable portion of these rocks, leaving only small areas such as that which outcrops immediately north of the old Copper Cliff mine. These rocks are again exposed to the west of the Ontario Smelting Works at Copper Cliff, forming the high ridges, which with some minor breaks, extend in a southeasterly direction a little beyond the boundary between Waters and Graham townships. Areas of very similar rocks are shown on the map as occurring in the township of Denison, the largest mass covering a considerable tract north of the Vermilion mine. The microscopical examination of most of the thin sections, representative of this rock, throws little or no light on its origin, and the exposures might very readily be mapped as belonging to a biotite or hornblende granite, while the prescence of a breccia of autoclastic character at the junction between this and the greywackes to the southeast might easily be interpreted as indicating the intrusion of a granitic rock through the greywacke.

These small, usually parallel, and seemingly dike-like forms of quartzo-feldspathic material are in reality thin beds of arkose material, which, originally continuous, have been drawn out, broken and separated during the process of stretching, while the enclosing rocks, having yielded more readily to deformation, give no evidence of autoclastic action. This quartzite is frequently 'blotched' in the vicinity of the railway line, the spots or blotches of a pale-reddish or pinkish colour being embedded in a network of greyish material, without however, any sharp or well-defined boundary between these two portions of the rock. It is made up principally of quartz, feldspar, biotite, muscovite and sometimes hornblende, the last mentioned mineral being especially conspicuous in those exposures of the rock crossed by the railway and wagon road to Azilda. This mineral occurs usually in long, slender prisms of a dark green colour, disposed at various angles to one another, and very evidently the product of secondary action.

The component minerals possess the irregular, interlocking outlines, with usually no suggestion of the rounding action of water, and, at first sight, has every resemblance to a granite or gneiss. An examination of the field occurrences of this rock is, however, much more satisfactory than that of the thin section under the microscope. At times, a series of beds can be traced out, differing considerably in composition and texture, the whole occurring in the form of a synclinal basin, resting upon the greywackes. This quartzite represents the most advanced type of a recrystallized arkose for which the term 'regenerated granite' has been proposed. (1) In the Huronian, there are no very large areas of conglomerate, and the exact position of these rocks is still a matter of doubt, but it is hoped that future investigation will, at an early date, enable a precise statement of the stratigraphical position to be made. From the investigations undertaken by the writer, these conglomerates would appear to lie at the base of a series, which, passing upwards into darker coloured feldspathic sandstones or greywackes, are in turn overlaid by feldspathic quartzites or arkoses which cover the larger portion of the southeastern part of the Sudbury map.

Such rocks are, as a rule, of a dark-grey colour, with disseminated, angular, subangular, or rounded fragments, chiefly of quartz, granite, diorite, &c. Thin sections exhibit a rock made up of fragments, chiefly of quartz, but also of orthoclase, plagioclase and microperthite. The most abundant composite fragments are granitite, composed mainly of microperthite and quartz, together with a little biotite. All of the larger individuals are embedded in a matrix, made up of much finer pieces of quartz and feldspar, together with biotite, sericite and a pale-green chlorite. Occasional grains of pyrite and also some of ilmenite occur. Excellent exposures of the last mentioned conglomerate may be seen along the line of the Canadian Pacific railway, immediately east of Sudbury, and in the vicinity of the north shore of Ramsay lake. As usual, these conglomerates are extremely local in their development, covering no very large extent of country, and the area to the east of Sudbury is, by far, the largest covered by such coarse, detrital rocks. Exposures of a very similar rock occur on lot 7, con I, of the township of Denison, to the south of a small lake, the conglomerate at this place underlying the quartzite.

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(1) Quart. Journ. Geol. Lon. Vol. LIII. (1897) p. 44.

Dr. Coleman mentions that, 'the most typical conglomerate in the region, however, extends as a much broken band from northeast to southwest, near Stobie mine, showing crowded pebbles and small boulders of more than half a dozen kinds, including granite, quartzite and several sorts of green schist, as well as greenstone.' (2) The occurrence of these conglomerates and the character of their pebbles indicate a probable lack of conformity in the Huronian, and it is quite possible that there is a lower and an upper series, the former made up of greenstones, schists, greywackes and highly altered quartzites (regenerated granites), overlaid unconformably by the conglomerates just mentioned, together with the overlying greywackes and feldspathic sandstones exposed in the southern part of the Victoria mines map, and the southeastern part of the Sudbury map. Besides these coarse detrital rocks, which are evidently consolidated shore deposits, there are certain pseudo-conglomerates or autoclastic rocks, formed, as already stated, as a result of pressure and deformation. These 'crush' conglomerates are especially abundant where the harder and more brittle quartzites come in contact with the schistose greywackes. Certain portions of the green schists, penetrated by granitic material, have likewise become autoclastic, through the stretching and rolling out of the rocks, while large portions of the greywackes themselves have been broken, the fragments separated and recemented together by similar, though somewhat coarser material.

(2.) UPPER HURONIAN?

(0.) OLDER? NORITES AND DIORITES.

Certain areas of gabbro and norite, with their derivative diorite, occur, which have no direct or visible connexion with the main mass of the nickel bearing norite. Most of these intrusive masses exhibit certain peculiarities of composition and structure, which all seem to possess in common, and by means of which they may usually be distinguished from the ordinary norite. The possesion of these characteristics, as well as their prevailingly greater alteration, suggests a probable difference in age, and the position assigned to them in the table of the geological formations exposed in this district is believed to be a very close approximation to the truth. Most of these masses, at least, are distinctly younger than any of the clastic rocks with which they come in contact, as they pierce and alter the highest beds of the quartzites, which occur in the region covered by the southern and southeastern portions of both the accompanying map-sheets. Their age, with regard to the granite or main mass of norite, is not known, as they nowhere occur in conjunction with these rocks. They are, however, older than the olivine-diabase, for dikes of this latest rock in the area are seen to cut them in many places.

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(2) Ann. Rep. Bur. of Mines, Ont., 1903, pp. 239 and 290.

With the exception of the Worthington mine, no large or economically valuable deposits of nickel and copper have been found in connexion with them, although the Mitchener and Totten mines, situated in the township of Drury, were opened on masses of these minerals which were directly connected with the Worthington mine intrusive. Other deposits of these sulphides are known to occur at several points, as for instance on lot 12, con. III, of Neelon township, where the pyrrhotite was found to contain 3·10 per cent of nickel, and on the north half of lot 4, con. VI, of Neelon township, but, so far as known, none of these are of sufficient dimensions to form working mines under present conditions.

One of these belts of norite starts in the township of Drury, to the south of the Canadian Pacific railway, and extends across the southern part of the township of Denison, ending a short distance east of the Vermilion river. The small areas shown on the map, as occurring on lot 12, con. II and III, of Denison, are of the same rock. Another band forms the high land between Trout, Clear and Whitefish lakes on the southeast, and McCharles and Simon lakes on the northwest. The highest portion of the ridge rises 220 feet above McCharles lake. The probable continuation of this band forms the higher hills northwest of Kelly lake, and with some minor breaks, the ridges formed by the outcropping of these hard rocks extend to the eastern end of Ramsay lake. To the north of the Canadian Pacific railway, and to the east of the town of Sudbury, the rock forms a series of exceedingly rugged and comparatively high hills, the highest of which rises over 1,000 feet above the sea. This mass of norite and diorite covers an area of about four square miles in this part of McKim and Neelon townships, sending off a long narrow arm, which crosses the sixth concession of the township of Neelon. The large irregular mass of similar igneous material, occurring in the eastern part of Neelon, and shown on the map as covering portions of the third, fourth and fifth concessions, is known to be directly connected with the same mass. With the exception of the smaller separated masses, with which the Frood and Stobie mines are connected, and which undoubtedly belong to the main mass of the norite, all of the smaller areas of massive, basic, igneous rocks, shown on the map, are made up of this or a closely related type of rock. In addition to these, considerable areas of massive diorite occur in intimate association with, and probably intrusive through, the older greenstones and tuffs which make up the larger portion of the area covered by the third and fourth concessions of Denison. These rocks are quite distinct from that which forms the main mass of norite, and are seemingly more closely related to this older norite intrusive. Similar areas of diorite rocks occur in the belt of older hornblende and tufaceous rocks which crosses the third and fourth concessions of Graham, to the south of the granite mass. Deposits of pyrrhotite, chalcopyrite, pyrite and cobaltiferous arsenopyrite are known to occur in connexion with these rocks, but they are not at present of economic importance.

In the field, outcrops of these older norites are pale-greenish, in contrast to the dark-greyish or black tones of the main mass of norite. They are, as a rule, finer in grain, eminently diabasic in texture and frequently show considerable masses of diorite pegmatite, or malachite, in this last respect differing from the ordinary norite, which is remarkably uniform in grain over the whole area. Under the microscope they contain less quartz, and the hornblende is always actinolite, and not the compact variety common in the diorite derived from the norite of the main mass.

Fresh representatives of this apparently older norite are comparatively rare, and the writer's specimens, selected with every care, at widely separated localities, contain only two specimens in which the pyroxenes are sufficiently fresh to permit of their identification, and even in the slides from these specimens by far the greater portion of the original ferromagnesian constituents are represented by the usual secondary serpentine and actinolite.

One of the hand specimens of the least altered phase of the diorite, collected near the eastern extremity of the band of greenstone between Whitefish and Simon lakes, is a pale greenish, medium-textured, massive greenstone, with little or no evidence of having been subjected to dynamic metamorphism.

The thin section shows a hypersthene-gabbro or norite, the greater portion of which has undergone advanced chemical alteration or decomposition. For the most part it is now made up of plagioclase and a serpentine closely related, if not identical with bastite. The latter mineral is very evidently secondary, and occupies very approximately the same position as the original bisilicate material, from whose alteration it has resulted. Occasionally, limited areas show the original pyroxenic minerals, in various stages of the bastitic alteration. A faintly pleochroic hypersthene or enstatite and diallage are both present, and some of the individuals or grains of these minerals are, with difficulty, distinguishable from one another. Both minerals are very nearly colourless, but the double refraction of the hypersthene is weak, while the diallage, on the contrary, shows brilliant chromatic polarization. Both pyroxenes show a faint, though distinct pleochroism, that possessed by the hypersthene being more decided. The index of refraction of the hypersthene is somewhat higher than that of the diallage, while the latter mineral shows frequent polysynthetic twinning. Both pyroxenes, however, decompose to the same pale-greenish, usually fibrous, but occasionally scaly bastite, often exhibiting brilliant polarization colours. In places, this bastite is being converted into a pale-greenish, feebly pleochroic, fibrous hornblende or actinolite, this uralitization being especially pronounced in the vicinity of the margins of the individuals. These bastitic areas contain very numerous, small, irregular scales and plates of a pale-brownish, apparently secondary biotite, and, in places, are crowded with small grains of secondary magnetite. The plagioclase, which, judging from the extinction angles, is labradorite, has a marked poikilitic development, this mineral extinguishing simultaneously over large areas, which in the thin section are separate either partially or wholly by intervening bisilicate material. This poikilitic effect is likewise noticeable in the hand specimen owing to the uniform reflection of light from the plagioclase individuals. Comparatively large, irregular grains of magnetite, probably titaniferous, are also distributed through the rock, while quartz occurs, filling up occasional interspaces between the tabular forms of feldspar.

Another specimen, representing a very fresh variety of this rock, was obtained from a small hill, west of a lumber road, on lot 11, con. V, of Neelon. Dr. Coleman mentions the fact that a specimen of this rock from the hilltop east of the town of Sudbury is 'a typical norite made up essentially of faintly pleochroic enstatite or hypersthene and plagioclase, the latter somewhat lath-shaped.' (1)

A thin section from a specimen obtained from the large mass of this rock, occurring to the southeast of the Evans mine, shows a greatly altered variety of this norite. The original pyroxene minerals are wholly converted into an aggregate of pale-greenish, brilliantly polarizing scales and fibres of serpentine, this, in turn, being converted, in certain instances, to actinolite. Pale-coloured biotite is abundant. A small amount of greenish-brown, compact hornblende is also present. The plagioclase, with the pale-brownish tints so common in these rocks, occurs in rather broad, lath-shaped or tabular, well-twinned crystals, which are, as a rule, quite fresh. Quartz is not very abundant, and some grains are intergrown with plagioclase, forming the characteristic granophyre. The iron ore is ilmenite, with borders of sphene. Apatite is abundant, in the usual slender, prismatic forms.

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, p. 296.

Another thin section, taken from a specimen obtained on the north half of lot 10, con. V, of Nelson, is still more decomposed, the pyroxene being replaced by a very pale yellowish-green serpentine and actinolite. All the intermediate stages in the conversion of serpentine to actinolite may be studied. Much of the feldspar is quite fresh and clear, with a pale-brownish colour, but the areas of this mineral have been invaded, to a considerable extent, by small fibres and crystals of actinolite. A little compact, brownish hornblende is also present. A large amount of zoisite occurs as a secondary product of decomposition. Ilmenite, largely altered to sphene, and occasional grains of pyrrhotite and chalcopyrite are also present, while quartz occasionally occupies the irregular interspaces between the plagioclase laths. Another specimen, from the north half of lot 4, con. VI, of Neelon, was also examined under the microscope. The rock may be referred to, at present, as a uralitic quartz-diabase. The original pyroxene is now represented by pale greenish, feebly pleochroic bastite and actinolite; much of the plagioclase is rather clear and fresh, but some has undergone considerable saussuritization. A little brownish hornblende is present. Sphene, in irregular grains, with black opaque cores of ilmenite, epidote and zoisite, are the principal other minerals noticed.

The actinolite diorite and schist, with which the deposits at the Worthington, Mitchener, Totten and Macdonell or Gersdorffite mines are associated, are evidently highly altered forms of this norite. These deposits possess certain peculiarities in common with one another, which distinguish them from the other ore bodies connected with the main mass of the norite. Some of the rock collected at the Vermilion mine is possibly of the same type and age, but this was not definitely ascertained. As is evident from the foregoing, it is manifestly difficult, if not impossible, in all cases, to decide the question of the identity of every individual specimen of altered norite, or even the various separated masses, but in a broad way these two norites are distinct and separate from one another, and the criteria already mentioned for distinguishing them will usually be found sufficient.

(3.) LAURENTIAN GRANITE AND DIORITE-GNEISSES.

The rocks usually classified as Laurentian comprise a series of foliated, eruptive rocks, mainly of granitic and dioritic composition, crossing the southeastern corner of the Sudbury map, in the townships of Dill and Neelon, in the vicinity of the Wanapitei river. These rocks possess a well-marked foliation, this structure being determined not only by the alternation of lighter and darker coloured bands, but also by the parallel disposition and alignment of the component minerals. The lighter coloured bands are usually of the prevailing flesh-red tint, and are made up largely of quartz with orthoclase, microline and microperthite .as the feldspathic constituents, and these minerals, together with biotite in varying amount, make up the bulk of the rock. The darker coloured bands contain less quartz and very abundant mica, with oligoclase as the principal feldspar. The biotite is often altered to chlorite. Muscovite and zircon are often present in small amount. Garnet is very abundant, of the prevailing almandine variety, and usually more or less rounded, but some of the well-formed individuals show the faces of the rhombic dodecahedron and icositetrahedron. Perhaps the most interesting mineral is cyanite, which is abundant in certain portions of the rock, occurring both in the micaceous and feldspathic bands. This mineral occurs in flat, blade-like crystals, with the prevailing bluish and whitish colours. In the micaceous bands the colour is especially deep, and of a beautiful azure tint, somewhat unevenly distributed or cloud-like in its effect, the colour being often deepest in the centre of the crystals, gradually becoming colourless towards the margin. These crystals are arranged, for the most part, parallel to the foliation, but some individuals are disposed at considerable angles to this structure. Sillimanite or fibrolite is also occasionally present, especially on slickensided or jointing planes, and shows abundant evidence of pressure and stretching. These gneisses are distinctly of eruptive origin, and their intrusion through the quartzites and other clastic rocks is everywhere apparent, where the line of junction is so exposed that the relationship between the two may be examined and studied.

4. UPPER HURONIAN (?) CLASTIC ROCKS.

The rocks, thus classified, occupy the large oval area situated immediately northwest of the main belt of the nickel bearing and kindred eruptives, and underlying the extensive clay plain which has already been described as so eminently suitable for agricultural purposes. As a result of the first geological examination these rocks were regarded by Dr. Bell as probably of Cambrian age, and have thus been coloured on all subsequent geological maps. Their precise geological age is still a matter of doubt, but the later work seems to indicate a close relationship both in origin and age, with the main masses of norite and micropegmatite. If, as seems probable from the work already accomplished, these several separate ranges of nickel bearing norite are, in reality, the exposed portions of one continuous laccolite, with occasional minor irregularities or offsets, then, as illustrated by Dr. Coleman, (1) these youngest clastic rocks of the district will, no doubt, be shown to occupy a synclinal trough, overlying this deep platter-shaped sheet of intrusive rock.

These rocks extend from the southeastern part of the township of Trill, to within a few miles of Wanapitei lake, the area being thus nearly thirty-five miles in length, with an extreme width of a little over eight miles.

They comprise, at the base, certain breccias and agglomerates, most of which, at least, are of pyroclastic origin, these rocks passing upward into black, bituminous shales, while they are, in turn, overlaid by a comparatively coarse greywacke or feldspathic sandstone.

The identification of the breccia at the base of this series as a consolidated volcanic ash was the result of microscopical studies undertaken by the late Prof. G. H. Williams, of material furnished him by Dr. Bell. The important fact of the occurrence, in these ancient rocks, of a volcanic glass breccia, the various minute details of structure being so exceptionally preserved through silicification as to permit of its positive recognition, has always been a matter of general interest and comment, especially amongst those geologists who regarded these earlier periods of the earth's history as characterized by exceptional and prolonged explosive volcanic activity.

A description of this comparatively rare type of rock was carefully prepared by Prof. Williams, and communicated to a meeting of the Geological Society of America, held on December 31st, 1890. These details were embodied in an appendix to Dr. Bell's paper on the nickel and copper deposits of this district, which was also read at this meeting. (2)

The material submitted for examination consisted of two small hand specimens, collected at the lowest falls on the Onaping river, in the township of Dowling. Prof. Williams' description (3) is so complete and satisfactory, that it may be quoted in this connexion.

‘In a hand specimen, this rock presents a nearly black felsitic matrix, in which are embedded sharply angular or slightly rounded fragments, varying from 1½ cm. in diameter, downwards to ultramicroscopic dimensions. These fragments are lighter in colour than the matrix, but differ considerably among themselves in their tint, structure and composition. The majority resemble chalcedony in appearance, others are greenish, while some of the largest fragments are now replaced by a single calcite individual. Occasional small grains of clear vitreous quartz may also be detected, while specks of pyrrhotite are everywhere abundant. Many of the angular fragments show distinctly under the lens a flow or vesicular structure, which is still more apparent in a thin section of the rock when seen under the microscope. The fragments, even down to those of the smallest dimensions, have the angular form characteristic of glass sherds produced by explosive eruptions, with more or less coarsely vesicular structure. The flow structure is as perfectly marked by sinuous lines of globulites and microlites which terminate abruptly against the broken edge of the glass particle, as in the most recent vitrophyre. Minute spots of pyrrhotite are scattered throughout the section. The groundmass is of a dark colour, owing to the massing in it of minute black globulites, to whose nature the highest magnifying power gives no clue. Between crossed nicols it is seen to be made up largely of chalcedonic quartz, which has changed the easily destructible glass into a sort of jasper. Chlorite is also abundant, frequently arranged as a border of radiating scales around the edges of the fragments, so as to coat them green in the hand specimen. The larger grains are always a fine mosaic of interlocking quartz, but some of the smaller ones are composed of a unit individual of clear vitreous quartz. The only other minerals which could be identified in the section are calcite and a few grains of a glassy striated feldspar. The presence of this latter mineral is very noteworthy, as we should expect it to have disappeared during the vicissitudes through which this rock has passed.'

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, (illustration 52) pp. 288-289.

(3) Ann. Rep. Geol. Surv., Can., Vol. V., 1890-91, Part F, pp. 74-76.

(2) Bull. Geol. Soc. Am., Vol. II., 1891, pp. 74-76.

In other localities this breccia shows a greater diversity in the character of the larger fragments, and composite rocks made up largely of quartz and feldspar, either granite or recrystallized quartzite, frequently occur. Plagioclase and quartz, usually in angular or sub-angular pieces, are very often represented, while epidote and hornblende, also mentioned by Dr. Coleman, are likewise present in the thin sections examined by the writer.

No complete chemical analysis has yet been made of the individual specimens examined by Prof. Williams, but Dr. Hoffmann made a silica determination, showing it to contain 60·23 per cent. Dr. T. L. Walker, however, has made an analysis of a specimen of this breccia, obtained from the north shore of Whitson lake, with the following results: (1)

$Si\ O_2$	59·93
$Al_2\ O_3$	12·12
$Fe\ O$	10·56
$Mn\ O$	trace.
$Ca\ O$	4·49
$Mg\ O$	5·19
$Na_2\ O$	3·80
$K_2\ O$	0·97
Loss by ignition	1·57
Total	98·63

Various sulphides, chiefly pyrite, but sometimes also pyrrhotite and chalcopyrite, are often abundantly disseminated through this rock, and not a few mining locations have been surveyed, intended to cover such deposits, which were regarded as possible mines. One of the most promising of these, visited by Mr. Leroy, was situated on the south half of lot 8, con. IV, of the township of Dowling, and the specimens secured were handed to Dr. Hoffman for assay. The hand specimen shows a massive pyrrhotite, with which is associated a little chalcopyrite and a somewhat larger proportion of gangue. The pyrrhotite, when freed from the chalcopyrite and gangue, was found by Mr. F. G. Wait (1) to contain 0·26 per cent of nickel with a trace of cobalt. Resting upon this breccia or agglomerate are certain black bituminous shales, often with well developed slaty cleavages. This rock is made up principally of minute fragments of quartz, with intervening scales of chlorite and sericite, and abundantly disseminated, black, opaque particles of carbonaceous or bituminous matter. These slates sometimes contain fissures occupied by anthraxolite or vein anthracite, and a large outcropping of such material in the township of Balfour occasioned considerable excitement some years ago. Samples of the surrounding rock, analyzed by Dr. Ellis, showed 6·8 per cent of carbon in the shale. (2) The highest rocks in this series are certain grey sandstones and shales, the former frequently containing concretions, which weather more rapidly than the matrix in which they are enclosed. Composite fragments can often be recognized with the naked eye, and the rock then assumes the character of a coarse grit. It is made up principally of angular and subangular grains of quartz, embedded in a finer-grained base, composed of feldspar, quartz, chlorite and mica. Zircon and tourmaline are also sometimes present. The dark colour of the rock is due to disseminations of innumerable, fine particles of opaque material, especially abundant in the feldspar, and which are probably ilmenite.

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(1) Quart. Jour. Geol. Soc. Lon., Vol. LIII., 1897, p. 45.
(1) Ann. Rep. Geol. Surv. Can., Vol. XIII., Part R, p. 35.
(2) Ann. Rep. Bur. of Mines, Ont., 1896, pp. 159-166.

(5) Post Huronian.

(A.) GRANITE.

It has been customary, of late years, to speak of certain areas of acid intrusives occurring in intimate association with the nickel bearing eruptive as the 'younger granites.' Reference has already been made to their strange and anomalous behaviour with regard to the sulphide bearing norite, for wherever the line of junction between these two classes of rock has been examined, it presents a series of apparently conflicting phenomena, which, in the present state of our knowledge, cannot be satisfactorily interpreted or explained. The larger proportion of the evidence, so far available, seems decidedly in favour of regarding these granite rocks as of earlier generation than the norite or gabbro, and even in the vicinity of the Creighton mine, where the immediate junction is characterized by the presence of a narrow belt of intermediate composition between the granite or norite, Dr. Coleman states that 'on the whole, however, the impression is formed that the granitoid gneiss is older than the gabbro, the latter sometimes growing finer-grained at the edge of the gneiss. (1) A reasonable explanation of the contradictory phenomena witnessed seems to be closely connected with the manner and rate of cooling of the granite batholith. This immense body of acid eruptive, as at present exposed at the surface by denudation, has not evidently resulted from the consolidation of a body of magma, the product of one simple act of plutonic activity, but is rather the result, locally at least, of several successive fusions and re-cementations, before the whole mass reached its final or present condition. The evidence of such successive periods of intrusion is furnished by a study of the granite mass itself, for although over the larger part of the area the granite is remarkably uniform in structure and composition, certain localities show rather sudden changes in these respects, with occasionally a sharp dividing line, thus indicating an apparent difference in age. All attempts, however, to trace out this apparent line of subdivision in detail, over any extent of country, proved futile, and the conclusion was reached that the whole mass is very closely synchronous, and that no appreciable lapse of time in a geological sense has occurred between the several dates represented by these different phases of the granite. The rate of cooling, moreover, was extremely slow, much more so in fact than the norite, so that it is possible that, in certain instances, some portions may have been sufficiently consolidated to permit of the cooling against it of the norite, while in areas not far distant some of the latest acid secretions of the granite penetrated and altered the norite or gabbro. There are two main types of these granites, the difference between the two being essentially one of structure, and although intermediate varieties between the two extremes are known to occur, such phases are relatively unimportant and may be ignored for purposes of general description. These two varieties are at present believed to be very approximately, at least, of the same age. One type of rock which occupies by far the largest area of any of these acid eruptives is a very decided 'augen' or porphyritic granitite-gneiss. In places, this seems to pass into a finer-grained and more massive type, with ill-defined or no foliation, thus resembling the second variety, the type of which, however, forms two smaller and separated batholiths occurring to the northeast of the main mass.

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, p. 245.

The coarser or 'augen' type presents such a strong resemblance, in every respect, to certain gneissoid rocks occurring in the Laurentian, that it was indicated as part of this formation in the first geological map. It constitutes a well marked batholith, intrusive through the older green schists and diorites, which it has greatly disturbed and altered, forming a belt to the south of the main mass of the sulphide bearing norite, and extending from the second lot in the township of Denison to a point a little east of the boundary between Snider and McKim townships, near the Copper Cliff mine. The mass is thus about thirteen miles in length, with an average width varying from one to two miles. It forms a very striking and beautiful rock, eminently suitable for building or ornamental purposes. It has been used in the building of the main office at Copper Cliff, as also for mantles in the manager's house at Victoria Mines.

Under the microscope the thin section shows the rock to be made up chiefly of microcline, orthoclase, albite, oligoclase, biotite and quartz, with epidote, sphene and apatite as accessory minerals and calcite, epidote, zoisite, sericite and chlorite as secondary products of decomposition. The orthoclase and microcline sometimes occur free, but, for the most part, are intergrown with the albite, forming both microcline and orthoclase-microperthite. The quartz is the usual granitic variety, frequently showing intense strain shadows and sometimes granulated into a fine interlocking mosaic.

The feldspars of the rock, although like the quartz often much cracked, broken and granulated, are comparatively fresh. Reddish-brown iron oxide has spread through the cracks, giving a cloudy or stained appearance to many of the grains. Much of the oligoclase has undergone considerable saussuritization, the resulting products being epidote, zoisite and sericite. It is usually stained a deep reddish-brown colour. The biotite is usually 'bleached' and has often undergone more or less complete chloritization. Sphene and epidote are often embedded in the biotite. Apatite is frequently present in the usual acicular prisms, while occasionally a little calcite was noticed in thin sections.

The 'augen' are usually made up of a comparatively coarse-grained aggregate of microperthite or microcline, together with a much smaller proportion of quartz. More rarely, it is a single crystal of feldspar, often a Carlsbad twin, rarely, however, with sharp or well defined boundaries.

In the vicinity of the Creighton mine the granite of the main batholith comes in immediate juxtaposition with the nickel bearing norite, while to the southwest in the vicinity of the Gertrude mine, as well as to the northeast from the North Star mine and beyond, considerable areas of the peculiar granite and greenstone breccia intervene between the two rocks. As has been stated, there is the clearest evidence at the Creighton mine of considerable reaction between the granite and norite, the former being often impregnated for a considerable distance from the contact with the nickel and copper bearing sulphides, while, in addition, certain portions of granite are unusually basic, presenting a rock of intermediate composition between the granite and norite, with deep flesh-red porphyritic individuals, often Carlsbad twins of orthoclase, microcline or microperthite, embedded in a groundmass made up principally of biotite, hornblende, epidote and sphene, the latter containing black opaque ores, presumably of ilmenite.

The finer-grained variety of granite is characteristic of two areas. The smaller one is situated immediately east of the Lady Violet mine, and extends a little north of the Manitoulin and North Shore railway, on the boundary between McKim and Snider townships. It covers a considerable portion of lot 1, con. IV, of the township of Snider.

The other and larger area extends from the main line of the Canadian Pacific railway, a little southeast of the Murray mine, northeast to within a quarter of a mile of the Little Stobie mine. It thus constitutes an oval area, measuring about three miles in length, and averaging about three-quarters of a mile in width. A microscopical examination of the thin section shows an aggregate of quartz, orthoclase, plagioclase, biotite, hornblende, magnetite and zircon. The rock has evidently been subjected to great crushing. The structure is by no means uniform, but larger fragments are embedded in a finer-grained mosaic, which has resulted, in great part, from their peripheral granulation. The magnetite is highly titaniferous, as it is often surrounded by borders of leucoxene or the more normal sphene. Besides these, a very small and irregularly shaped area crosses the Manitoulin and North Shore railway, immediately east of Pump lake, on lot 1, con. IV, of Snider township. It has a general resemblance to the coarse 'augen' variety. This small mass measures about 850 feet long and from 150 to 500 feet wide.

About two miles west of the Murray mine, Walker mentions that the nickel bearing eruptive is cut by two separate intrusions of fine-grained pinkish, biotite-granite, which send off apophyses into the surrounding greenstone. The wider of the intrusions is about 100 yards broad, while the smaller is less than sixty yards. The microscope shows that quartz, orthoclase, plagioclase and biotite, are the chief constituents. Considerable areas, in the vicinity of the line of junction between these granites and the older greenstones, are characterized by the presence of a breccia, made up of an extremely intricate intrusion or penetration of the greenish schistose rocks by dikes and irregular masses of granitic material. The chief alteration noticed in connexion with the greenstone is the development of biotite at the expense of the original hornblende, and the replacement of the plagioclase by a fine mosaic of secondary plagioclase, quartz and epidote, the rock being thus a well formed mica or biotite schist. Subsequent differential movements have occasioned very considerable deformation, and some portions of the resultant rock mass represent very perfect and characteristic pseudo-conglomerates. Areas of these breccias are often big enough to be shown on maps of ordinarily large scale. They are especially noticeable east and southeast of the Gertrude mine, and betwen this and the Creighton mine, and some of the cuttings of the Manitoulin and North Shore railway, between these two mines, have been made through hills of this breccia. It seems to occupy a lenticular area, intervening between the norite and the granite, the widest part being a little over three-quarters of a mile, while the length from northeast to southwest is about three miles. To the northeast, in the vicinity of the North Star mine and beyond, as far as Clarabelle lake, considerable areas are underlaid by this breccia, while in the neighbourhood of the Murray mine they are especially noticeable and well developed. The manager's house at Copper Cliff is located on a rocky knoll, made up of this breccia, and a comparatively narrow band of this rock extends for a short distance in a southwesterly direction.

In addition, the main mass of the granite batholith contains frequent inclusions, often of large size, of these older greenstones and schists, the reason for their presence and occasional abundance being readily explained by Dr. Daly as due to 'stoping,' as he terms the phenomenon of the detaching of portions of the original material overlying or enclosing a batholith, and the inclusion of such fragments in the mass of the original magma. (¹)

(5.) Post Huronian.

(B.) NICKEL BEARING ERUPTIVE.

Soon after the discovery of these nickel and copper deposits it was remarked that all of the rich and extensive ore-bodies occurred in intimate connexion with certain basic eruptive rocks of medium texture, and which for convenience of description, and in the absence of more precise information, were usually referred to under the names of greenstone and diorite. The first published microscopical descriptions were all in substantial agreement, in regarding the prevailing type of the nickel bearing eruptive as made up essentially of plagioclase and hornblende, with a smaller proportion of biotite and quartz, while ilmenite and apatite, with variable quantities of pyrrhotite and chalcopyrite, were the usual accessory constituents. The rock was, therefore, regarded as an intrusive gabbro or diabase, which owing to subsequent metamorphism, had its pyroxenic components changed to secondary hornblende or uralite. Rocks quite like these had been studied in many regions, where they could be traced with certainty into basic eruptives of normal character, and it was confidently predicted by the late Prof. G. H. Williams, who was the first to make any detailed petrographical examination of these rocks, that 'specimens might be collected at some of these localities which would establish positively both the original form, and the course of alteration of the present specimens.' (¹)

Included in the same suite of specimens as the foregoing, all of which had been sent by Dr. Bell to Prof. Williams for identification and description, was one which had been collected near the Dominion mine, in the township of Blezard, but which, in the hurry of a first examination, was regarded as occurring in the form of a dike. This rock, the exceptional character of which was noted at the time by

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(1) Amer. Jour. Sc., Vol. XVI., 1903, p. 108.
(1) Ann. Rep. Geol. Surv. Can., Vol. V., 189?-91, Part F, pp. 60 and 62.

Prof. Williams, and which was described as a 'quartz-hypersthene-gabbro with accessory biotite' (²), was in reality a practically unaltered representative of the nickel bearing eruptive, although its identity as such was not suspected until some years afterwards.

All of these first microscopical determinations, therefore, showed a normal type of greenstone, differing in no essential particular from others similarly altered, and with no apparent reason for the development of such unusually large and rich deposits of sulphide material. At the same time, the field and prospectors' term of diorite was justified, as also the names proposed after more detailed microscopical examination, such as uralitic or gabbro-diorite, uralitic diabase, etc.

It is to be regretted, therefore, that although great care was exercised in the collection of these first or type specimens, attention was directed chiefly to the selection of material in immediate association with the ore-bodies, and the rocks thus obtained were in such advanced stages of decomposition that no very definite or precise information was possible in regard to their original composition or true affinities. As a consequence of this the opinion prevails that the whole of the eruptive in the vicinity of these nickel deposits is completely altered, whereas the very opposite appears to be the case, and most of the writer's collection of fresh and unaltered material was obtained in the immediate vicinity of the various mines. In this connexion it may be remarked that some of these hand specimens, containing as much as from 5 to 10 per cent of the sulphides, have undergone so little metamorphism as to permit of the positive identification of all the prevailing minerals, including hypersthene, enstatite, diallage, olivine and labradorite.

In 1892 the late Baron von Foullon published the first determination of the nickel bearing eruptive occurring in the vicinity of the Murray mine, showing it to be a gabbro, closely related to the norites, his description being prepared after a study of material collected at this locality in the summer of 1890. In 1893, Dr. A. P. Coleman identified the eruptive of the Northern Nickel range as a gabbro containing both diallage and hypersthene.

The true significance of these discoveries and isolated descriptions was not, however, fully appreciated until the appearance of Dr. Walker's results, the issuing of this publication marking a very signal advance in our knowledge regarding the origin and relationship of these sulphide deposits and their associated rocks.

The nickel bearing eruptive, characteristic of the three main belts or ranges, may, for purposes of description, be considered under two divisions.

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(2) Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91. Part F, pp. 77-78.

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I. A basic portion:—Including certain gabbroid rocks, chiefly, at least, of the norite facies, with their derivative diorites, with which the nickel and copper bearing sulphides are immediately associated.

II. An acidic portion:—Comprising large areas of rock of granitic type, with well marked gneissoid structure, the prevalence and abundance of the graphic intergrowth of the quartz and feldspar, known as granophyre or micropegmatite, having suggested the name 'micropegmatite,' by which this rock is now generally known.

The least altered phase of the basic portion of the eruptive is represented by what may be referred to as 'norite.' The rock is sometimes called a 'quartz hypersthene-gabbro,' but for general purposes the former name is preferred.

The microscopical examination shows the rock to be an eruptive of rather exceptional character and interest. It belongs to the general family of gabbros, but with distinct traces, and, at times, well marked diabasic or ophitic structure. The prevalence and usual preponderance of hypersthene or enstatite show its close affinity with the norites, while it contains, what is very exceptional for such a rock type, an abundance of original quartz. In fact, many specimens could be secured which contain nearly as much quartz as an ordinary hornblende granite. In some instances, noticeably at the Copper Cliff mines, a large quantity of micropegmatite or granophyre is present, the feldspathic constituent of this graphic intergrowth being usually plagioclase. Exposures show a massive, medium to coarse-grained, dark-greyish, greenish-grey or brown rock, which is often almost black in colour on freshly broken surfaces. Scales of deep brown biotite are usually conspicuous, while the quartz is perhaps equally so, in very characteristic sapphire-blue or purplish grains, the colour which is often seen in the phenocrysts of quartz-porphyries.

These rocks do not offer any very effectual resistance to processes of decomposition and erosion, and, as a consequence, the area characterized by their presence is, generally, one of low relief.

Spheroidal weathering is characteristic, but not so pronounced as in the case of the later dikes of the olivine-diabase.

The orthorhombric pyroxene, either hypersthene or enstatite, shows a distinct approach to perfection of crystallographic outline, and, in many cases, was the first of the essential minerals to form. In occasional instances the hypersthene is unaccompanied by a monoclinic pyroxene, as in some of the specimens collected in the vicinity of the Blezard mine. It is often, by far, the most abundant of the coloured constituents, as at the Murray mine, where the diallage is only occasionally represented, while almost the whole rock mass is made up of hypersthene, in various stages of decomposition, the small and infrequent interspaces being occupied by plagioclase. The hypersthene is, as a rule, rather faintly pleochroic, although specimens from the vicinity of the Blezard mine, and from a railway cutting about one mile and a half northwest of the Murray mine, are very strongly pleochroic, rose red to pale yellowish-green. The enstatite is also colourless in thin section, and, in contradistinction to the hypersthene, exhibits little or no pleochroism. Both the hypersthene and the enstatite are very liable to decomposition, so that, in most cases, areas of this mineral are replaced by an aggregate of light-green, non-pleochroic, brilliantly polarizing, fibrous or scaly serpentine (bastite). This alteration is often accompanied by the separation of minute grains of magnetite. In most cases, even the fresh individuals of hypersthene are bordered by a compact, strongly pleochroic, green hornblende, which is doubtless an original constituent. This primary hornblende, likewise, forms borders on areas showing the complete bastitic alteration. In addition to this, there is undoubted secondary hornblende resulting from the alteration, first of the bastite into actinolite, and this, in turn, to the ordinary type of green hornblende.

The monoclinic pyroxene, which is usually present in subordinate amount, is likewise frequently bordered by primary hornblende, and thus the individuals of these two pyroxenes cannot be distinguished from one another in specimens which have undergone any advanced decomposition. Sometimes, both pyroxenes show the presence of the characteristic, minute, tabular interpositions or schillerization products, but, as a rule, these are absent.

The diallage is distinguished from the orthorhombic pyroxene chiefly by the absence of pleochroism, its inclined extinction, and frequent polysynthetic twinning, while it usually shows a lower index of refraction with higher double refraction. Olivine is present in small amount in the norite obtained from the Little Stobie mine, but most of it is altered to an aggregate of deep-coloured scaly serpentine, talc and magnetite. Biotite is an almost invariable constituent and is usually rather abundant in large plates and is undoubtedly of primary origin. The plagioclase is usually in broadly twinned, stout, lath-shaped or tubular crystals, whose frequent interlacing arrangement produces the characteristic, rude, ophitic structure. Separations by means of Thoulet's heavy solution, as well as the extinction angles, show that this plagioclase is labradorite. The presence of innumerable, brown, dust-like inclusions, presumably of ilmenite, gives to the feldspar its prevailing dark colour.

Quartz and occasionally granophyre fill most of the irregular interspaces between the other constituents, although, in the norite from the Creighton mine, microline almost invariably accompanies this interstitial quartz. Apatite, magnetite, which is usually highly titaniferous, zircon and grains of pyrite, pyrrhotite and chalcopyrite are almost always present. These sulphides are distinctly of primary origin, and were among the earliest of the minerals to crystallize from the original magma, antedating even the magnetite, in some cases, for grains of pyrrhotite were noticed completely enclosed by the iron ore. The sulphides occur, for the most part, intimately associated with, and frequently embedded in the coloured constituents, in much the same way as the magnetite, from which they can only be distinguished by the difference in colour in reflected light. The pyrrhotite and chalcopyrite are often very intimately associated, so that they are extremely difficult of separation, even the smallest grains showing intimate intergrowths of these minerals with one another. These sulphides frequently occur in those portions of the norite which have suffered so little from dynamic metamorphism that only an occasional dislocation of a plagioclase crystal is noticed, while the same exposures have been so little affected by hydrochemical agencies that such readily alterable minerals as hypersthene, enstatite, olivine and diallage are still plainly recognizable in such specimens. The sulphide material, in such cases, is often not subordinate in amount, but is so abundantly disseminated as to characterize the rock, and justify the name of 'pyrrhotite-norite' which is sometimes applied to it.

Although a considerable number of specimens were secured, representative of the comparatively unaltered norite, by far the larger proportion of the material collected consisted of a massive, usually coarse gabbro-diorite in various stages of alteration. Very few of these show even traces of dynamic metamorphism, and, as a rule, the ophitic structure, produced mainly by the interlacing arrangement of the plagioclase crystals, is quite undisturbed. The alteration is mainly due to hydrochemical agencies, and affects the pyroxenic minerals, decomposing these to a pale yellowish-green serpentine, sometimes of the ordinary type, but usually of the bastite variety. Actinolite also results from the alteration of the pyroxenes. The compact borders of primary hornblende often surrounding the original pyroxenes are evidently made up of much more stable material, not having been affected by any of these changes. The areas formerly occupied by the pyroxene are, therefore, replaced by bastite or actinolite, the hornblende borders remaining unaffected, the individuals thus decomposed being referred to as uralite. No distinction can be drawn between grains which represent hypersthene or diallage, as both of these minerals apparently decompose to closely related, if not identical, material. The labradorite is usually quite fresh, in tabular or broad blade-like forms, with a brownish colour of varying shades, which is so prevalent in the norites. Occasionally it shows incipient decomposition to the usual saussuritic products, mainly sericite, but also epidote and zoisite. Biotite is always present and conspicuous in large plates with strong pleochroism. It is sometimes intergrown with the hornblende and has also undergone considerable 'bleaching.' It usually contains comparatively large, irregular grains of magnetite. Quartz is always present, and sometimes abundant, filling up the irregular interspaces between the other constituents. Highly titaniferous magnetite and apatite are also always present, but in small amount, while the pyrrhotite and chalcopyrite vary in amount, from occasionally disseminated grains, to such quantities as ensure the use of the mass as an ore of nickel and copper.

In addition to the norite and diorite a more acid rock of granitic composition and prevailing gneissoid structure occurs, which cannot be separated genetically from the more basic portion with which the sulphides are more directly associated. This rock has usually been referred to 'micropegmatite,' a name first suggested by the late Prof. G. H. Williams. (1) There is no sharp line of demarcation between the acidic and basic portions of the nickel bearing eruptive, but the change, though gradual, is usually sharp enough to enable a boundary to be placed betwen these two types, with tolerable accuracy. Outcrops of this rock are evenly banded or foliated, with a distinct strike and dip, usually porphyritic,weather a pale reddish or greyish colour and are frequently intersected by irregular and often intricate vein-like masses of quartz, evidently of pegmatitic origin. On freshly exposed surfaces the rock is usually dark coloured; with abundantly disseminated, small, reddish or yellow phenocrysts of feldspar. Orthoclase is often present in considerable amount, and, towards the outer edge of the mass, is the predominant feldspathic constituent, but plagioclase (oligoclase or oligoclase-andesine) is usually more or less abundant. Microperthite and microcline are also often present, but in subordinate amount. Much of the feldspar is somewhat turbid, owing to decomposition. Biotite is the prevailing ferromagnesian mineral, and much of it is 'bleached' and altered to chlorite. It is usually in small irregular, tattered scales and plates, arranged in narrow, approximately parallel bands, gently curving around and among the larger phenocrysts of feldspar. The abundance of the biotite, and its frequent alteration to chlorite, give the prevailing dark colour to the rock on fresh surfaces. The transition type between the micropegmatite and the norite shows a varying proportion of hornblende, which mineral, as a general rule, diminishes in amount in passing outward from the norite, although certain bands of relatively greater basicity show an appreciable amount of this mineral, even at a considerable distance from the line of junction. One of the most noteworthy points, in connexion with this gneissoid rock, is the prevalence and abundant development of micropegmatite or granophyre, and also the fact that plagioclase and quartz are most frequently the component minerals forming this graphic intergrowth. The micropegmatite, together with the bisilicate material, chiefly biotite or chlorite, and sometimes hornblende and accessory epidote, ilmenite and sphene, form a groundmass, in which the comparatively large phenocrysts of feldspar, chiefly plagioclase, but sometimes also orthoclase and microperthite, are embedded. The granophyre or micropegmatite very often stretches out in various directions from a central portion or body, made up of well twinned and rather sharply bounded crystals of plagioclase. The effect of pressure is very noticeable in all the thin sections, not only in the strain shadows, but also in the dislocation of the feldspar individuals, and the abundant development of the fine interstitial quartz and feldspar.

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(1) Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part F, p. 78.

On the first geological map this micropegmatite was included with, and coloured as, a part of the Laurentian, the reddish colour, gneissic structure, and general behaviour, being the main factors which determined this classification.

The variation in the chemical composition, marking the transition from the norite to the micropegmatite, is well illustrated by a series of analyses made by Dr. T. L. Walker (1) from specimens obtained along the Blezard mine crossing. The specimens range from south to north, from I to V. Analysis No IV is by Mr. C. B. Fox, M.A.

——	I.	II.	III.	IV.	V.
SiO_2	49·90	51·52	64·85	69·27	67·76
TiO_2	1·47	1·39	......	0·78	0·46
P_2O_5	0·17	0·10	0·24	0·06	0·19
Al_2O_3	16·32	19·77	11·44	12·56	14·00
Fe_2O_3	......	0·47	2·94	2·89	......
FeO	13·54	6·77	6·02	4·51	5·18
CaO	6·58	8·16	3·49	1·44	4·28
MgO	6·22	6·49	1·60	0·91	1·00
MnO	trace	trace	trace	trace	trace
K_2O	2·25	0·70	3·02	3·05	1·19
Na_2O	1·82	2·66	3·92	3·12	5·22
H_2O	0·76	1·68	0·78	0·76	1·01
Totals	99·03	99·71	98·30	99·35	100·29
Specific gravity	3·026	2·832	2·788	2·724	2·709

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(1) Quart. Jour. Geol. Soc. Lon., Vol. LIII, February, 1897, p. 56.

According to the present state of our knowledge there are three main belts of norite with which workable deposits of the various sulphides carrying nickel and copper occur. Until recently these were believed to be entirely distinct and separated, but the later, more detailed geological examinations are tending to prove that these are all portions of a geological unit, and all referable to one continuous mass. They have always been regarded as essentially the same in origin and mineralogical composition and approximately, at least, of the same geological age. Two of these belts are not included on the accompanying map-sheets and, so far, none of the deposits occurring in association with them have ever been operated as mines, producing ore for shipping and smelting purposes.

The most northerly of these bands, known as the 'Northern Nickel range,' starts from the old Ross mine (W. R. 5), near the line between lots 5 and 6, on the line between cons. III and IV, of the township of Foy, and extends in an east-southeast direction through the township of Bowell, where on lot 6, con. II, it branches. One offset runs southeast, into the townships of Lumsden and Morgan, where its limits have not been definitely ascertained. The main band, however, runs to the east, cutting across the township of Wissner, and crosses the Vermilion river, immediately north of Bronson lake. Trending still more to the north it connects with the large area of basic rocks occurring to the west of Wanapitei lake. This mass extends, for the most part, in a southerly direction, and, as far as at present ascertained, is buried beneath the sand and gravel plains of the eastern part of Garson and the western portion of Falconbridge. It is, as yet, a matter of conjecture whether this mass is continuous with the southern or main belt of the norite, which to the east of lot 3, in con. III, of Garson, is likewise covered up by the heavy mantle of drift. It is probable, however, that this main belt is continuous beneath the drift, as far, at least, as the outcrops of norite occurring on cons. IV and V, of Falconbridge. It may be possible, with the assistance of delicate magnetic instruments, to trace out this connexion, but this work will be difficult and tedious, on account of the great accumulation of drift material, which is sometimes over 100 feet in depth.

A second important band of norite occupies an approximately intermediate position between the other two, and so may be referred to as the 'Middle Nickel range,' although it is likewise known as the Levack Nickel range,' while Walker refers to it under the name of the 'Windy Lake eruptive.' According to present information this band starts about lot 12, con. III, of the township of Trill, extends north and northeast through this township into Cascaden, and crossing under Windy lake goes on uninterruptedly through the northwest corner of Dowling, to lot 2, con. IV, of Lavack township. Little information is available in regard to the geology of the intervening stretch of country between this point and the Ross mine, and it is possible that this gap may be filled in by extending this norite range still farther to the northeast. The area to the east and southeast is known to be occupied by the acid differentiate of the norite, (micropegmatite) so that a connexion between the Levack and the Northern Nickel range is well within the limits of possibility. To the southwest the Levack range reached within two miles of the old Sultana and Trillabelle nickel mines, so that, in this direction also, a connexion may be made with the southern or main belt of the norite. The celebrated Levack nickel deposits are developed along the northern contact of this band with the granitite-gneiss included as Laurentian.

By far the largest and most important band of norite, however, is what is known as the 'Southern or Main Nickel range,' a portion of which has been described by Dr. Walker under the name of the 'Whitson Lake eruptive.' Its southeastern limit, in all probability, consists of a comparatively narrow band of basic eruptive material, crossing the southern portion of Trill, and extending thence into the northeastern part of Drury township. Its possible connexion in this direction with the Middle or Levack Nickel range has already been discussed. From Drury, the band of norite extends eastward, crossing the southern half of lot 12, con. V, of Denison. From this point it has been traced continuously, in a northeast direction, for a distance of about thirty-five miles, as far as lot 8, con. III, of Garson, where the exposures pass under the extensive accumulation of drift material. At the Victoria mines the basic portion of the intrusive is rather less than a mile in width, but at the crossing of the Vermilion river this width is increased to one mile and three-quarters, while in the vicinity of the Creighton mine the norite is a little over two miles wide. Through the townships of Snider, McKim and Blezard the width of the norite is fairly uniform, averaging about one mile and a half, gradually becoming narrower until Garson township is reached, where the basic portion of the nickel bearing eruptive is scarcely half a mile in width.

On lot 2, con. IV, of the township of Snider, this main belt of norite sends off a narrow, dike-like extension or offset, in a southeasterly direction, on which are situated most of the mines of the Canadian Copper Company, at Copper Cliff. This band runs across the northeast end of Clarabelle lake, and crossing Lady Macdonald lake it runs with unbroken continuity as far as No. 2 mine, where its further extension southward is covered up with drift. Mine No. 2, with its extensions to the north, mines No. 4, 5 and 6, are all immediately associated with this narrow, dike-like form, while the Lady Violet mine is located at the eastern junction of the norite with the granite, a short distance northeast of the point where it joins the main mass.

It is unnecessary to furnish similar details of the distribution of the micropegmatite or acid portion of the nickel bearing eruptive, but the area underlaid by this rock is considerably in excess of the basic portion, as shown on the map.

The famous old Copper Cliff mine is a veritable chimney of ore, occurring in connexion with an isolated stock of norite, which comes in contact with feldspathic quartzites and green schist. The openings in the vicinity of the Ontario Smelting Works belong to three separate masses of norite, which are surrounded by banded tuffs and quartzite. It is difficult to obtain specimens from the small area of norite on which the Evans mine is situated sufficiently free from the sulphide material for purposes of examination.

The Little Stobie mine, Dominion, Davis property, Kirkwood and Cryderman mines, are situated on the borders of the main belt of norite with green schist. The Stobie and Frood mines occur in conjunction with comparatively small stocks or areas of norite, which are separated from one another. The Elsie mine occurs at the junction between norite, on the one hand, and green schist and hornblende porphyrite, on the other. The Murray mine occurs at the junction between the granite and greenstone breccias and green schists on the one hand, and the main band of norite on the other; while the old Cameron mine, farther to the northeast, is found at the junction between the granite and the norite. The North Star and Creighton mines occur at the junction between the granite and the norite.

The various openings known as the Gertrude mine are located along the junction between the main band of norite and a breccia made up of the granite intrusive through the older greenstone and schists. The main shaft of the Victoria mines is at the end of a small offset, connected with the main mass at the junction between the norite and the older green schists. Without exception, all of these immense bodies of sulphide material are situated at the immediate contact between the intrusive norite and the older rock in such a way as to indicate in the clearest manner their common origin.

(C.) LATER DIKES OF OLIVINE DIABASE.

The rock usually designated olivine diabase, and characteristic of what has been called the later dikes, is very uniform in mineralogical composition and structure. Hand specimens show a rock which is dark-grey, greenish-grey, to almost black, with spheroidal rusty weathering, which is very characteristic. In many instances, exposures exhibit a rude basaltic structure and are frequently porphyritic, with phenocrysts of yellowish or greenish labradorite, often an inch or even more in diameter. The alteration of these phenocrysts produces the mineral 'huronite,' so named by Thomson. These dikes possess well marked selvages of fine-grained, occasionally glassy material (tachylite), and present every gradation between basalt and diabase. The thin section of the fairly coarse rock shows a remarkably fresh olivine-diabase, made up chiefly of plagioclase, augite and olivine. The plagioclase is the principal constituent and is generally quite fresh and glassy, although occasionally somewhat turbid, as a result of incipient decomposition. Being the earliest constituent to crystallize, it is in idiomorphic, well twinned, tabular or lath-shaped crystals, which have a marked ophitic arrangement. The extinction angles clearly indicate labradorite. The twinning is according to the albite law, but a combination of the albite and pericline law is very common. Occasional individuals exhibit twinning according to the rarer baveno law. The augite shows a very irregular or jagged outline, with characteristic imperfect or interrupted cleavages. It is reddish to violet brown in colour, and very distinctly pleochroic. The olivine occurs in more or less rounded, pale yellow grains, and sometimes fills in the spaces between the feldspar crystals. It is remarkably fresh, but occasionally shows decomposition to a deep green, compact serpentine (antigorite).

Apatite is very abundant, in the usual acicular prismatic forms, and the opaque constituent is probably ilmenite. Some of the thin sections are very instructive, especially as regards the order of crystallization of the various mineral constituents. Apatite was certainly the first to crystallize, as it occurs in sharp, well defined, elongated prisms which are embedded in, or pierce the other constituents. The labradorite has, in most cases at least, crystallized before the augite, but its relation to the olivine is not quite so distinct. In some cases the olivine has the rounded outline it usually assumes when its crystallization is not interfered with, but often it may be found occupying the triangular interspaces between the feldspar laths, or sharply moulded upon them. It appears, therefore, that the period of the crystallization of the olivine certainly overlapped that of the labradorite, although, in general, the olivine is distinctly earlier. Most of the ilmenite, likewise, is earlier than the plagioclase, but occasional individuals contain crystals of olivine and plagioclase, showing that some of the ilmenite formed after the olivine and plagioclase.

A quantitative analysis of a specimen from the big dike near Murray mine gave Dr. Walker (1) the following results:

SiO_2	47·22
Al_2O_3	16·52
Fe_2O_3	3·32
FeO	12·40
MnO	0·04
CaO	9·61
MgO	3·33
K_2O	0·67
Na_2O	3·40
TiO_2	3·62
P_2O_5	0·33
BaO	0·01
CuO	trace.
NiO	0·0275
CoO	0·0055
Loss by ignition	0·30
Total	100·803
Specific gravity	3·01

These dikes of olivine-diabase are distinctly later in age than the rest of the associated rocks. They cut the greenstones and associated micropegmatite, as well as the ore bodies themselves. They likewise cut the tuffs, breccias and quartzites, although one dike was noticed which did not reach the summit of the quartzites, but was cooled against the upper beds.

As a rule, most of these dikes are remarkably fresh and unaltered, and all of those mapped as occurring in the vicinity of the Murray mine are of this description. On the other hand, with the single exception of the large dike which runs in a northwest direction near the Ontario Smelting Works, all of the others are much altered and decomposed, and thin sections prepared from these cannot be distinguished from the finer grained and more basic, altered facies of the norite. The boundaries between the bisilicates and plagioclase are not well defined, the latter containing scattered shreds and grains of hornblende and biotite. The plagioclase shows the same cloud-like arrangement of sub-microscopic inclusions, presumably of ilmenite. The hornblende is in small, strongly pleochroic individuals, and is very abundant. Biotite is also abundant, while the ilmenite is largely represented by sphene. The ophitic structure still remains, but is not so pronounced. Most of the plagioclase is quite fresh, but some of it is altered to a saussuritic aggregate. Quartz is fairly abundant, filling in small, irregular interspaces between the other constituents. Small grains of sulphide material are also disseminated through the rock. The occurrence of such a rock in dike-like form, with the same mineralogical composition of the norite, indicates that these dikes, at least, are later and differentiated portions of the norite, representing the dying efforts of the very pronounced and long continued vulcanism. The occasional presence of olivine in the norite of the Little Stobie mine, and the recognition of quartz in some of these later dikes, have supplied the links hitherto missing and necessary for a proper understanding of the relationship existing between these two rocks. As shown by Walker, in the analysis quoted of a fresh type, this olivine-diabase contains small quantities of copper, nickel, and cobalt, which the same author regards as original constituents of the olivine-diabase magma. The relations of these dikes to the various ore bodies through which they are intruded show distinctly that these latter had already attained their present dimensions at some time previous to the intrusion of the dikes. For the most part they have a fairly constant direction, but present frequent broad curves and occasional faults. Two of the largest dikes met with vary in width from 150 to 200 feet, and were traced with practically unbroken continuity from the northwest corner of McKim township, southeast to Ramsay lake. There is no local enrichment whatever of the ore bodies in the vicinity of the dikes, as has frequently been surmised. The influence occasioned by their passage through these ore bodies is extremely local and very insignificant. In the vicinity of the Copper Cliff and Murray mines, and the area intervening, many of these dikes have been encountered, and it has been found possible over this limited area to accurately determine and map their dimensions and direction, and although the prevailing direction is perhaps northwest and southeast, many of them occupy fissures with courses very widely divergent.

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(1) Quart. Jour. Geol. Soc. Lon., February, 1897, p. 63.

MINERALS ASSOCIATED WITH THE NICKEL AND COPPER OF THE SUDBURY MINING REGION.

PYRRHOTITE AND CHALCOPYRITE.

The ore bodies, with which the nickel and copper are immediately associated, consist essentially of pyrrhotite ($Fe_8 S_9$) which is by far the most predominant constituent, and chalcopyrite ($Cu Fe S_2$) usually in much smaller amount, and a varying proportion of gangue, consisting mainly of the associated eruptive or its constituent silicates. The nickel present in the ore bodies is not, as so many have supposed, an essential constituent of the pyrrhotite, isomorphously replacing an equivalent amount of iron, but is mainly present, at least as a distinct and magnetically separable nickel-iron-sulphide known as pentlandite. This mineral is, as a rule, very intimately associated with the pyrrhotite, but occasional hand specimens from the lower levels of the old Copper Cliff mine show a rather intimate association of nearly pure pentlandite and chalcopyrite. The pyrrhotite and chalcopyrite will be described more fully in that portion of the bulletin dealing with the composition of the ore bodies.

PENTLANDITE.

This mineral is usually very intimately associated with the pyrrhotite, and is so finely disseminated through the mass of this mineral that a separation can only be effected by very fine grinding. Though pentlandite itself is feebly magnetic, and in finely powdered form is attracted by an ordinary hand magnet, advantage is taken of the great difference in the magnetism of these two minerals to effect their separation. It requires repeated trials to eliminate the last traces of the pyrrhotite, but this has been successfully done by Penfield, Browne and Dickson, and their analyses which are quoted give all necessary details of the chemical composition of this mineral, showing it to be very uniform over the whole district. It is essentially the same as the original pentlandite (eisennickelkies), analyzed by Scheerer, but contains more nickel, and less iron and sulphur. Sometimes, as at the Worthington mine, it occurs in tolerably large pieces, which can be readily distinguished from the enclosing pyrrhotite, but even these contain a considerable amount of disseminated pyrrhotite, so that material thus secured rarely assays over 30 per cent of nickel. The mineral is very abundant at the Creighton mine, and can be readily recognized on account of its perfectly developed, octahedral parting. It is somewhat paler in colour than the pyrrhotite, varying from steel-grey to silver-white, and almost invariably breaks with flat surfaces, which are planes of parting, parallel to the octahedron. The mineral, however, in freshly broken material, cannot readily be distinguished from the equally fresh pyrrhotite, especially if the planes of parting are imperfectly developed. Exposure to the weather brings about a rapid change in colour to a peculiar pale bronze yellow, which is very characteristic and quite distinct from the pyrrhotite.

The material obtained by Penfield (¹) was crushed and sifted to a grain of from 1-2 mm. in diameter, and the pyrrhotite was extracted by means of an ordinary magnet. The pentlandite, for analysis, was further carefully selected by hand-picking.

Similar, preliminary, careful preparation of material was used by Mr. C. W. Dickson (²). The following are the analyses:—No. 1 (Penfield); 2-4, (Dickson); 5-9, (Browne) (³). Analyses 5-7 inclusive, are stated to contain some pyrrhotite as fine dust. Analyses 10 and 11, are by Scheerer (⁴) of the pentlandite from Lillehammer. Analysis No. 2, is from Creighton mine; No. 3, Worthington mine; No. 4, Frood mine; No. 5, Copper Cliff mine; No. 6, Stobie mine; No. 7, Evans mine; No. 8, Copper Cliff mine (hand-picked); No. 9, Evans mine (hand-picked).

	1	2	3	4	5	6	7	8	9	10	11
Ni	34·23	34·82	33·70	34·98	35·05	34·70	34·12	35·00	34·90	18·35	21·07
Co	0·85	0·84	0·78	0·85	....	....	....	....	....	....	....
Fe.....	30·25	30·00	29·17	30·04	29·80	29·90	29·95	30·30	29·60	42·70	40·21
S...	33·42	32·90	32·30	33·30	34·35	33·90	35·43	33·50	33·55	36·45	36·64
Cu	....	....	....	....	....	....	....	....	....	1·16	1·78
Gangue .	0·67	....	....	....	....	....	....	....	....	....	....
	99·42	98·56	95·93	99·17	99·20	98·50	99·50	98·80	98·05	98·66	99·70

The ratios in Prof. Penfield's analysis are S· (Fe + Ni)=1·044: 1·047, almost 1 : 1, or that of a normal sulphide (Ni + Fe) S. The ratio of the Fe: Ni is 1 : 1·32, while in that from Lillehammer, it is about 2 : 1. Dickson remarks that the ratio of the (Ni + Fe): S varies from 10·91 to 11·07: 10, and points out that this ratio 11: 10 is not accidental, but constant for all analyses of pure material. He, therefore, suggests that the formla for this mineral be written $(Fe + Ni)_{11} S_{10}$ which seems rather clumsy and an unnecessary refinement of expression of material, which, even when every precaution is taken, is still not absolutely pure. The formula of the Lillehammer pentlandite is given as 2 Fe S + Ni S. The ratio of nickel to cobalt in the Sudbury pentlandite varies, running from 40 to 42: 1, is worthy of remark, as this proportion is almost identical with that found in the ore bodies.

A magnetic separation of the nearly pure sulphides forming the ore from the Creighton mine was made by means of the Wetherill separator, the material thus used being crushed to different degrees of fineness, and graded by means of sieves. The original product showed an assay value of 1.20 per cent of copper, and 4.87 per cent of nickel, with 2.49 per cent of insoluble matter. The very fine material gave the cleanest separation, and some of that which passed through a

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(1) Amer. Jour. Sc. (3rd Series) Vol. XLV., 1893, pp. 493-494.

(2) Trans. Amer. Inst. Min. Eng. Albany Meeting, February, 1903.

(3) Eng. and Min. Jour., December 2nd, 1893, Vol. LVI., p. 565.

(4) Dana, System of Mineralogy, 6th Ed., 1892, p. 65.

100-mesh sieve, was divided into three products which may be distinguished from one another as strongly magnetic, feebly-magnetic and non-magnetic. The feebly magnetic product showed the presence of 30.41 per cent of nickel, and the non-magnetic 30.36 per cent of nickel. A complete analysis, and an adjustment of the various constituents, showed that the feebly magnetic portion consisted of chalcopyrite and pentlandite, in the proportion of 1 : 21, while the non-magnetic product showed these same materials present in the proportion of 1 : 7.

PYRITE.

A sulphide which presents all the ordinary physical characters of pyrite, such as hardness, specific gravity, colour, lustre, and magnetism, is by no means uncommon in most of these deposits, and can generally be found when a special search is made for this mineral. Large cubical crystals of pyrite are mentioned by Dr. Coleman, (1) as occurring in fissures, with quartz and calcite, at the Elsie mine, but the assay of one of these showed no nickel. Dickson mentions the fact that a number of his samples from the Copper Cliff mine were associated with secondary quartz, calcite and millerite. Pyrite was also noticed occurring with pyrrhotite, chalcopyrite and danaite, at the Century Copper mine on the north half of lot 4, con. IV, of the township of Graham. A determination by Mr. F. G. Wait of the Geological Survey showed 0·49 per cent of nickel, with a trace of cobalt. Dr. Walker (2) found what he regards as a true nickeliferous variety at the Murray mine, and has published a full description and analysis of the specimen. The following is the analysis under 1, and if the mineral be considered as pyrite, in which part of the iron is replaced isomorphously by nickel, the explanation is given under II and III.

I		II			III	
Nickel	4·34	Nickel		4·34	NiS_2	9·12
Iron	39·70	Sulphur	49·31	4·78 44·53	FeS_2	83·49
Sulphur	49·41	Iron	39·70	38·96 ·74	Fe_3O_4	1·02
Moisture	·10	Oxygen (calculated)..		.28		
Copper	traces	Water....				·10
Insoluble	5·76	Insoluble				5·76
Arsenic	none					
		Total				99·49

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(1) Ann. Rep. Bur. of Mines, Ont. 1903, p. 281.
(2) Amer. Jour. Sc., Vol. XLVII., 3rd Series, April 1894, pp. 312-314.

A peculiar greyish-green, bronze-coloured, non-magnetic mineral was found by Mr. McVittie on the location where the Gertrude mine now is. The mineral occurred massive, with small crystals of magnetite, and specks of chalcopyrite disseminated through it, in a streak about six inches wide, adjoining the granite. An analysis of the mineral, after removing the magnetite, gave Mr. Mickle (1) the following results under I, while under II is given the proportions, omitting the insoluble matter and recalculating to 100.

	I	II
Iron	37·28	41·48
Sulphur	46·54	57·79
Nickel	5·95	6·62
Copper	0·10	0·11
Insol	9·66	.....
Total	99·53	100·00

Mr. Mickle regards this as an aggregate made up of pyrite, millerite and chalcopyrite, the composition, as given above, practically agreeing with such a mixture. A very similar compound is found at the old Beatrice mine (Davis property), on lot 1, con. III, of the township of Blezard. After an analysis of this material, Dr. Emmons (2) decided that the mineral was a new nickel-iron-sulphide, and proposed for it the name 'Whartonite.' The mineral is not homogeneous and is very evidently a mixture. It has a peculiar bronze-yellow colour, is cellular, the cavities being lined with minute crystals, with an intermediate, finely granular material. It was usually referred to by the miners as 'matte,' on account of the resemblance to this artificial product. The chemical analysis by Emmons showed it to contain (1):

Nickel	5·40
Iron	42·90
Sulphur	45·00
Insoluble	4·80
Total	98·10

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, p. 282.

(2) Ann. Rep. Bur. of Mines, Ont., 1892, p. 170.

(1) Ann. Rep. Bur. of Mines, Ont., 1892, p. 170: also Jour. Am. Chem. Soc., Vol. XIV., No. 7.

MARCASITE.

The mineral thus designated is distinguished from pyrite chiefly by its silver white colour, which even weathering only deepens slightly to a very pale, bronze-yellow. Samples of such material, submitted to Prof. Penfield by Mr. C. W. Dickson, were considered by him as massive marcasite. The analyses conform to the formula FeS_2 and show the presence of from 2 to 4 per cent of nickel, probably as pentlandite. Dr. Walker mentions the occurrence of marcasite in the midst of the usual sulphides at the Murray mine, but assays of this material failed to show the presence of any nickel. Perhaps the most noted specimens which may be included under this name are those for which the name 'blueite' was proposed by Dr. S. H. Emmons (1). The mineral has a metallic, somewhat silky lustre, while the colour is pale olive-grey inclining to bronze. The type specimens came from the Gersdorffite mine (lot 12, con. III, Denison), which, at the time, was worked under option by the Emmons Metal Company. The mineral also occurs on the lot to the south (lot 12, con. II), as well as at the Totten mine (lot 1, con. II, Drury), and at the Worthington mine (lot 2, con. II, Drury). Dr. Emmons' analysis showed the presence of 3·5 per cent of nickel with 38·8 per cent of iron, and 5·4 per cent of insoluble matter, but the sulphur 52·3 per cent, calculated by difference, is evidently too high. At the Gersdorffite mine the nickeliferous marcasite occurs in association with niccolite, gersdorffite, pyrrhotite and chalcopyrite, in a small quartz vein cutting a hornblende schist.

At the Worthington and the Totten mines this very white nickel ore occurs in the form of circular or oval patches, which are very conspicuous, embedded in the pyrrhotite, chalcopyrite, and associated with rocky matter. An assay of a specimen from the Worthington mine, by T. L. Walker, showed the presence of 4·5 per cent of nickel. A specimen was also sent to Prof. F. W. Clarke, chief chemist of the U.S. Geological Survey, and an analysis of this ore was made by Dr. F. W. Hillebrand, his results being reported as follows: (2)

Iron	38·36
Nickel	4·57
Manganese	0·10
Sulphur	45·11
Sulphuric acid	0·95
Carbonic acid	1·49‡

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(1) Jour. Am. Chem. Soc., Vol. XIV., No. 7; also Ann. Rep. Bur. of Mines, Ont., 1892, p. 168.

(2) Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part SS, p. 116.

‡ Calculated on the supposition that all the calcium exists as carbonate.

Magnesia	0·41
Insoluble	4·80
Water at 100° C.	0·55
Water combined	?
Loss and oxygen	?
Total	98·25

A consideration of the above analysis shows that it agrees very closely with the assumption that the nickel is present in the form of pentlandite disseminated through the marcasite. Prof. Clarke, in his letter, states: 'It seems to me that the material is a mixture, not a definite species. Your Sudbury minerals deserve an exhaustive study, and the work would be well repaid.'

MILLERITE.

The simple or normal sulphide of nickel is occasionally met with in some of the mines, and may be the source of some of the nickel of these deposits. Agreeably with its formula NiS, this mineral should contain, when pure, 35·3 per cent of sulphur and 64·7 per cent of nickel. Undoubted slender crystals of millerite were found at the Copper Cliff mine, in workings 150 feet below the surface. Another specimen containing this mineral, associated with pyrrhotite, was obtained at the Beatrice mine, on lot 1, con. III, of Blezard township. Dickson mentions having found 'small bunches of hair-like crystals of this mineral, in the cavities of some radiating pyrite, mixed with calcite.' He regards the millerite as undoubtedly secondary, and probably derived from pre-existing pentlandite.

POLYDYMITE.

This mineral occurs in association with chalcopyrite, chalcocite, pyrrhotite and pyrite at the Vermillion mine, lots 5 and 6, con. IV, of the township of Denison. It is steel-grey, massive, and exceedingly alterable in the air. It has a specific gravity of 4.5. An analysis of carefully selected material gave Clarke and Catlett the results under I, (1). A good sample of the Vermilion ore, analyzed by Mr. Browne, after deducting 1·5 per cent of silica, gave the results under II, evidently impure polydymite. (2)

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(1) Amer. Jour. Sc., Vol. XXXVII., 1889, pp. 372-374.

(2) Eng. and Min. Jour., Dec. 2, 1893, Vol. LVI., p. 566.

	I	II
Nickel	41·96	36·85
Iron	15·57	18·70
Sulphur	40·80	38·43
Copper	0·62	4·47
Silica	1·02	.....
Totals	99·97	98·45

These figures give approximately the formula Ni_3FeS_5. Neither cobalt nor arsenic could be detected. If we deduct silica, together with the copper reckoned as admixed chalcopyrite, and recalculate the remainder of the analysis under I, to 100, we get the following figures:

Nickel	43·18
Iron	15·47
Sulphur	41·35
Total	100·00

In short, the mineral has the composition of Ni_4S_5 with about one-quarter of the nickel replaced by the iron, which agrees with Laspeyres' polydymite, of which it is doubtless a ferriferous variety. The polydymite from which the above was selected came from a mass in which an average of 35·39 per cent of nickel and 5·20 per cent of copper had previously been found.

A specimen of the so-called polydymite was presented to the writer by Mr. F. L. Sperry, at one time chemist of the Canadian Copper Co. The mineral at the time was known to be impure, but was the best sample which could be secured for the Museum. The material was mainly polydymite, in a gangue composed of diorite and small quantities of quartz. Carefully selected material—which, however, it was found still contained a little intermixed gangue and chalcopyrite—was found by Mr. R. A. A. Johnston to contain 40·80 per cent of nickel with no cobalt.

SPERRYLITE.

Sperrylite was first found at the Vermilion mine in the gossan or loose material, and was named after Mr. Francis L. Sperry of the C. C. Co. by Profs. Horace L. Wells and S. L. Penfield, of the Sheffield Scientific School, who examined and described this new species (1). The material as received consisted of a heavy, brilliant sand, composed largely of the sperrylite, but intermixed with this a considerable number of fragments of chalcopyrite, pyrrhotite and some silicates could be seen. After the material was purified it was found to contain some transparent grains which proved on examination to be oxide of tin or cassiterite (SnO_2).

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(1) Amer. Jour. Sc., Vol. XXXVII., 1889, pp. 67-63.

Sperrylite is isometric, simple cubes are common, octahedrons are exceptional, while the majority of the crystals are combinations of the cube and octahedron. Hardness is between six and seven, as it scratches feldspar, but not quartz. The specific gravity is 10·602. The crystals have no distinct cleavage, but are very brittle, and break with an irregular, probably conchoidal fracture. The chemical composition, according to the mean of two analyses, was as follows:—

Arsenic	40·98
Antimony	0·50
Platinum	52·57
Rhodium	0·72
Palladium	trace.
Iron	0·07
Cassiterite or oxide of tin	4·62
Total	99·46

The composition is, therefore, represented by the formula $PtAs_2$, a small portion of the platinum and arsenic being replaced respectively by rhodium and antimony. The colour of the mineral was nearly tin-white, or about the same as metallic platinum. The fine powder is black. Nearly all the grains showed extremely brilliant, crystal faces, though most of the crystals were fragmentary in size, usually 1/50 to 1/500th of an inch in diameter.

The presence of an appreciable amount of iridium was expected by Professor Wells, but careful search failed to reveal even traces of this element.

Sperrylite is regarded as the source of the metals of the platinum group, which are invariably present in appreciable amounts in the bessemer matte, assays of the Copper Cliff and Victoria mines mattes showing from 0·4 to 0·5 oz. per ton. Wherever occurrences of this mineral have been examined it is directly and intimately associated with the chalcopyrite, so that matters rich in copper contain a large amount of platinum, while those containing very little copper show a correspondingly small amount of platinum. In Dr. Walker's (1) analysis of the bessemer matte from the Murray mine the presence of iridium and osmium is noted in almost equal amounts, but in Prof. Wells' analysis, as noted above, these metals were not detected. Baron von Foullon concludes from the absence of these elements that there is another mineral present, which contains the iridium, but although this is possible Dr. Walker considers that a more likely explanation is that, in some cases, part of the platinum in sperrylite is replaced by the elements iridium and osmium.

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(1) Amer. Jour. Sc., Vol. I., 1896. p. 112.

NICCOLITE.

This mineral, in intimate association with gersdorffite and with variable quantities of intermixed pyrrhotite, chalcopyrite and pyrite, has been found in connexion with the occurrence of two small 'stocks' or intrusions of quartz-mica-diorite (altered norite), in the township of Denison. This diorite forms two small hills, which rise above the surrounding country, which is underlaid by the slaty variety of the tuffs or greywackes, these rocks surrounding the diorite on all sides. One of these masses, known as the McConnell or Gersdorffite mine, is situated in the southeastern corner of lot 12, con. III, of Denison, while the other, constituting what is known as the Hiram Robinson property, is on the northeastern corner of the west half of lot 12, con. II, of the same township. The country rock in the immediate vicinity is usually a more or less schistose diorite or hornblende schist, produced by the shearing of the more massive diorite, of which most of the hill is composed. The rock is made up, chiefly, of irregular crystals of hornblende closely aggregated together, the few and small remaining interspaces being occupied by quartz and plagioclase. At the Gersdorffite mine, from which the first and finest specimens of this mineral and the associated gersdorffite were obtained, they occur in a small vein, interfoliated with a chloritic actinolite schist, at the north side of the small area of diorite shown on the map. The vein consists mainly of quartz with a very small amount of feldspar and calcite, with grains and small disseminated masses of the sulphides already mentioned, the most abundant and conspicuous being the niccolite and especially the gersdorffite. No analysis of the niccolite was made. This, when pure, is represented by the formula $NiAs$=arsenic 56·1, nickel 43·9=100·0. It usually contains a little iron and cobalt, also sulphur, while sometimes part of the arsenic is replaced by antimony. The mineral occurs massive, and the peculiar pale, copper red is quite distinctive. A sample containing niccolite and gersdorffite was submitted by the writer to Mr. T. L. Walker who found them too intimately associated to separate for analysis. He, therefore,, made an analysis of the two minerals together, which resulted as follows: (1)

Nickel	20·87
Cobalt	0·64
Copper	trace.
Iron	2·43
Sulphur	10·60
Arsenic	26·04
Silica	26·70
Alumina	5·43
Magnesia	7·29
Lime	
Soda	
Total	100·00

GERSDORFFITE.

This mineral was first recognized in a small sample brought to the Geological Museum, in 1891, by Mr. Eagleson, who had obtained the specimen from Mr. Dan. O'Connor, of Sudbury, the owner of the Gersdorffite mine, where it had been found. The particulars of the association of the mineral have already been described under niccolite. When pure the mineral is essentially a sulph-arsenide of nickel, with the formula NiAsS or NiS_2, $NiAs_2$ = sulphur 19·3, arsenic 45·3, nickel 35·4 = 100·0. Iron replaces the nickel, often in considerable amount, also sometimes cobalt. The following is the description of the specimen collected by the writer in 1891, prepared by Dr. Hoffmann and Mr. R. A. A. Johnston. (2)

Structure, for the most part lamellar, but occasionally granular, a few minute, fairly well developed crystals exhibiting the forms of the octahedron and cubo-octahedron, with the faces of the octahedron predominating, were also observed. Colour, steel-grey, here and there tarnished blackish. Specific gravity (after correction for a little included quartz) at 15·5° C., 6·231.

The material upon which the analysis was conducted, although selected with all possible care, and, so far as could be seen, apparently pure, nevertheless contained, it was subsequently found, a very appreciable amount of quartz. Its analysis afforded Mr. R. A. A. Johnston the results given under I. Deducting the gangue (silica), and recalculating the remaining constituents to one hundred parts, we obtain the figures given under II.

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(1) Ann. Rep. Geol. Surv. of Can., Vol. V., 1890-91, Part SS, p. 118.
(2) Ann. Rep. Geol. Surv. of Can., Vol. V., 1890-91, Part R, p. 22.

	I	II
Arsenic	40·31	46·96
Sulphur	14·34	16·71
Nickel	22·50	26·32
Iron	6·78	7·90
Cobalt	1·73	2·01
Copper	0·09	0·10
Gangue (quartz)	13·55	.....
Total	99·39	100·00

This mineral had not previously been identified as occurring in Canada.

MORENOSITE.

This mineral, which is also known as 'Nickel vitriol' is a hydrous, nickel sulphate ($Ni\ SO_4 + 7\ H_2O$) = sulphur trioxide 28·5, nickel protoxide 26·6, water 44·9 = 100·0. 'It occurs as a greenish-white and pale apple green incrustation on associated gersdorffite, niccolite, chalcopyrite and pyrrhotite at the McConnell or Gersdorffite mine (lot 12, con. III, of Denison); also, but more sparsely, as a greenish-white incrustation on some of the nickeliferous ore of the Worthington mine (lot 2, con. II, Drury).' (1) It has also been noticed at the Wallace mine on Lake Huron.

ANNABERGITE.

Some specimens of gersdorffite, which had been in the drawers of a mineral cabinet for about a couple of years, were found to have undergone a partial decomposition, with the formation of hydrous nickel arsenate. The material which came from the Gersdorffite mine, (lot 12, con. III, Denison), consisted of gersdorffite, with a few scattered particles of chalcopyrite. The nickel arsenate, which occurred both lining and filling cavities in the gersdorffite was, in the former case, in the form of botryoidal, globular, or mammillary crusts of a greenish-yellow colour, pale grass-green, and honey-yellow to brownish colours, and exteriorly of a sub-vitreous lustre, whilst that filling the cavities was compact and amorphous, texture colloid, of a greenish-yellow colour and waxy lustre, also occasionally, but more rarely, earthy, chalk-like and dull. (2)

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(1) Ann. Rep. Geol. Sur. Can., Vol. VI., 1892-93, Part R, p. 27.
(2) Ann. Rep. Geol. Sur. Can., Vol. VI., 1892-93, Part R, p. 27.

DANAITE (COBALTIFEROUS ARSENOPYRITE).

This mineral is a sulph-arsenide of iron (FeAs S), with part of the iron replaced by cobalt. Agreeably with the formula given above it should contain, theoretically, arsenic 46·0, sulphur 19·7, iron 34·3 = 100·0. It is not abundant in the Sudbury district, and has only been recognized as occurring in two localities, and in both of these places it is found in association with the older diorites and hornblende schists. The first place in which it was found was on the north half of lot 6, con. III, of the township of Graham, this lot forming a portion of what is known as the Russell location or property.

The mineral is massive, with a steel-grey colour. Intermixed with it were small quantities of white, translucent quartz, some pyrrhotite, a little galena and a trifling amount of chalcopyrite. The specific gravity at 15·5° C. = 5·988.

An analysis by R. A. A. Johnston'(2), of carefully selected material, is given under I. Deducting the gangue of silica, and recalculating to 100 we obtain the results under II.

	I.	II.
Arsenic	40·16	42·22
Sulphur	17·92	18·84
Iron	31·69	33·32
Cobalt	3·89	4·09
Nickel	0·88	0·93
Antimony	0·57	0·60
Gold	trace.	trace.
Gangue (quartz)	4·77	
Totals	99·88	100·00

This mineral also occurs in considerable quantity on the north ½ lot 4, con. IV, of the township of Graham, at a deposit which was being worked for copper, and known as the Century Copper mine. It is present in intimate association with pyrrhotite, chalcopyrite and pyrite, abundantly disseminated through a hornblende and biotite schist ,and also through a pale greyish quartzite, which is embedded in the hornblende schist.

SMALTITE.

This mineral, so far as known, is rare in the Sudbury district, although it occurs in large masses in the Timagami region, to the northeast. It is a cobalt diarsenide, $CoAs_2$ = arsenic 71·8, cobalt 28·2 = 100·0. This mineral was observed by Mr. E. B. Kenrick, of the Geological Survey of Canada, in the form of minute crystals, with well marked octahedral cleavage, in association with chalcopyrite, from the township of McKim. (1)

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(2) Ann. Rep. Geol. Sur. Can, Vol. V., 1890-91, Part R, p. 19.

GALENA.

This mineral has been found at all the mines, wherever search was made for it. It is the common sulphide of lead PbS = sulphur 13·4, lead 86·6,=100·0; usually contains a little silver. It generally occurs in thin seams penetrating the other sulphides. It may be the source of much of the silver found in all the mattes produced from the Sudbury ores. It shows the usually bright lead-grey colour, with distinct cubical cleavage. No analysis was made of this mineral in immediate association with the ore bodies.

CHALCOCITE.

This mineral, also known as copper glance, has only been described as occurring at Vermilion mine, in Denison township. Its occurrence at this place is noticed by Mr. Johnston, in a specimen which was given to the writer by Mr. F. L. Sperry. This specimen consisted of chalcocite and chalcopyrite, through which was disseminated some polydymite. Some of the fragments were coated with green carbonate of copper. Mr. Johnston found that the specimen contained 9·40 per cent of nickel with no cobalt. No chemical analysis of the chalcocite was made.

BORNITE.

This mineral is mentioned as occasionally seen by Mr. C. W. Dickson. Some of the chalcopyrite obtained at the Vermilion mine, which was greatly weathered, has a general resemblance to this mineral. No undoubted bornite was, however, noticed by the writer.

MAGNETITE.

This mineral is an invariable constituent of the norite, and is always more or less titaniferous. It is generally disseminated in minute grains through the ore bodies, but, as a rule, in very subordinate amounts. Occasionally, small masses of titaniferous magnetite are associated with the pyrrhotite, and an analysis of such a mass, from the Murray mine, gave Dr. Walker, (1) 18·34 per cent of titanic acid. The largest mass yet noticed was recovered from the workings of the Clarabelle mine, where, according to Capt. McArthur, about five tons were found enclosed in the sulphides. This magnetite is readily attracted by the magnet, and contains grains of pyrrhotite and chalcopyrite, as well as small portions of a green silicate. (2)

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(1) Ann. Rep. Geol. Sur. Can., 1886, Part I, p. 13.

CASSITERITE.

The purified material from which the analysis of sperrylite was made by Professor Wells, of Yale University, contained, as stated, 24·6 per cent of oxide of tin, in the form of minute transparent grains. These were carefully examined and pronounced to belong to the species cassiterite.

NATIVE COPPER.

Dendritic or leaf-like forms are ocasionally met with, as at the Vermilion mine where a few specimens of chloritic schist were obtained, showing native copper developed along the planes of cleavage. L. P. Silver has a specimen of the diorite, obtained from the twelfth level of the Copper Cliff mine, showing a good deposit of leaf copper, which he considers must have been formed by the reduction of the chalcopyrite, by reducing solutions leaching through the rock. (3)

NATIVE GOLD.

Samples of the ore obtained from the Vermilion mine contain appreciable quantities of native gold, and specimens may be obtained from this mine showing abundantly disseminated grains and strings of gold, often of large size. All of the mattes produced from the Sudbury ores contain gold, the percentages of this metal varying in the bessemer matte from strong traces to 0·3 oz. per ton. The average amount would be about 0·15 oz. of gold per ton, although Silver (4) reports having found 0·75 oz. of gold in a matte which contained 39·64 per cent of nickel and cobalt, and 42·75 per cent of copper.

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(1) Quart. Jour. Geol. Soc. Lon., Vol. LIII., Feby., 1897, p. 52.
(2) Ann. Rep. Bur. of Mines, Ont., 1903, p. 281.
(3) Jour. Can. Min. Inst., Vol. V., 1902, p. 536.
(4) Jour. Can. Min. Inst., Vol. V., 1902, 534.

GRAPHITE.

Dr. Coleman(2) reports having found a few scales of graphite in the country rock occurring on the dump at the Lady Macdonald mine.

CUBANITE.

David H. Browne,(3) for some time chemist to the Canadian Copper Company, at Copper Cliff, found this mineral, which is represented by the formula $Cu\ Fe_2S_4$ = sulphur 35·4, copper 23·3, iron 41·3=100·0, in the roast heaps, being one of the products formed during the roasting.

In addition to the above mineral varieties mention may be made of the fact that quartz, calcite, dolomite and ankerite are found in association with the massive sulphides, but these minerals are relatively very unimportant, and even at such deposits as the Victoria mines considerable quartz has to be added to the furnace charges on account of the basicity of the associated rocks. Nearly all of the gangue occurs as intermixed norite or diorite.

Composition of the ore-bodies.

The ore bodies with which the nickel and copper are immediately associated consist essentially of a mixture of sulphides, in which pyrrhotite (Fe_8S_9), is, by far, the predominant constituent; chalcopyrite is almost invariably present, and usually in considerable amount, although proportionately much less than the pyrrhotite. It has been conclusively proved by means of the magnetic separations carried on by Browne, Dickson, and the writer that the nickel present in these ores is all contained in the pentlandite, although the first mentioned authority is still inclined to the belief that the small amount retained by the magnetic portion or pyrrhotite proper occurs in part, at least, as an essential constituent of the pyrrhotite. This pentlandite is usually very finely and uniformly distributed throughout the whole mass, although in certain mines, as the Creighton, Copper Cliff, Evans, and very noticeably the Worthington mine, it occurs in spots and patches, often as much as half an inch to an inch, or even more, in diameter, of fairly pure material. The relative abundance of this nickel-iron-sulphide determines the richness, or otherwise, of the containing deposit. Pyrite also contributes to the formation of these deposits, and much of it is nickeliferous. Present opinion varies somewhat in regard to the form in which the nickel is present in this compound, Dr. Walker's researches tending to prove that this element replaces isomorphously an equivalent amount of iron in chemical combination, while others regard intermixed pentlandite as the source of the nickel. Certain other sulphides of nickel already mentioned and described also contribute to the unusual richness of these deposits, but these are relatively much less important, and many of the occurrences, where such minerals are present, are, so far as known, of no commercial importance. A varying amount of gangue, usually of the associated eruptive, but occasionally also of the older green schists, greywackes and even quartzite, is always present. The percentage of such intermixed rocky matter is sometimes unusually large, as in certain portions of the Elsie and Murray mines where material has been used in large amount, which consists of sulphides and rock in about equal proportion, while, in other instances, as at the Creighton and Victoria mines, the sulphides are so pure and massive that large quantities of associated norite have to be added to the furnace charge to act as a flux. Magnetite, and certain of the silicates peculiar to the norite, usually more or less decomposed, such as hornblende, actinolite, serpentine or chlorite are almost always present. A comparatively small amount of quartz, calcite, dolomite, and very occasionally crystals of tourmaline, molybdenite and apatite, are also found.

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(2) Ann. Rep. Bur. of Mines, Ont., 1903, p. 284.

(3) Ann. Rep. Bur. of Mines, Ont., 1903, p. 284.

The pyrrhotite and chalcopyrite are not, as a rule, so intimately commingled as to form a homogeneous mass, but each may be described as occurring in pockets, spots, bunches or threads, in the other. The chalcopyrite is not so closely intermixed with the pyrrhotite, but tends to isolate itself rather in patches or spots, usually enclosing, but occasionally enclosed by, the pyrrhotite. It is sometimes possible to separate considerable masses of chalcopyrite, assaying over 30 per cent of copper, or pyrrhotite, that will only show traces of that metal. In practice, however, careful examination and trial have proved that the two minerals are too intimately associated to make sorting by hand at all practicable. Although the chalcopyrite seldom occurs free from the pyrrhotite, large and massive deposits of the latter occur comparatively free from copper. The first ore shipped from the Gertrude mine was so free from copper that it was proposed to utilize it for the production of ferro-nickel, and this deposit was purchased by the Lake Superior Power Company, with this object in view. Analyses made of a large mass of the Creighton mine ore obtained near the surface, show the nickel to vary from 4·87 per cent to 5·31 per cent, with 0·72 per cent to 1·20 of copper. The prevailing intimacy of association, however, of the pyrrhotite and chalcopyrite will perhaps be better appreciated by mention of the fact that hand-picked specimens from the Evans, Stobie and Copper Cliff mines, collected and analyzed by Mr. Browne, (1) showed the presence of from 13·86 to 15·71 per cent of copper with a sufficient quantity of intermixed pyrrhotite and pentlandite in the same to assay from 1·28 to 2·47 per cent of nickel. On the other hand, selected nickel ore from Copper Cliff mine, with 8·12 per cent of nickel, contained only 0·80 per cent of copper, while similarly picked ore from the Evans mine containing 5·36 per cent of nickel showed the presence of only 0·49 per cent of copper. In certain of the deposits, as for instance at the main shaft of the Victoria mines, the nickel and copper are almost identical in quantity, assays of a large number of samples, neglecting the insoluble matter, showing the presence of 3·66 per cent of each metal. At the Dominion, Murray and Elsie mines, the nickel is usually nearly double that of the copper. Thus, Mr. George Attwood, M.E., (2) at one time manager of the Dominion Mineral Company, under date of March 18th, 1891, stated that the 'kies' or metallic portion of the Blezard mine averaged 4 per cent of nickel and 2 per cent of copper, this result being the average of a large number of assays, as also of the practical working of the mine. About the same date Mr. F. R. Daw, then manager of the Murray mine, stated that an average of the ore smelted at this mine contained 1·5 per cent of nickel and 0·75 per cent of copper. Other assays of an average sample of ore from this mine show 0·9 per cent of copper, with 1·5 per cent of nickel and 46 per cent of insoluble, or the equivalent of 1·66 per cent of copper and 2·76 per cent of nickel, in the pure sulphide material.

The Gertrude and the Creighton mines, and especially the latter, are deposits in which the nickel is often present in the ore in the porportion of 3 or 4 to 1. In the first years of the development of the mines of the Canadian Copper Company the copper was greatly in excess of the nickel, and assays of specimens of raw ore, taken without selection from these mines, showed a range in copper from 4·03 to 9·98 per cent, with an average of 6·44 per cent, while the nickel, in the same specimens, varied from 1·12 per cent to 4·21 per cent, with an average of 2·38 per cent. This preponderance of the copper was maintained for some time, for an average of two samples of the blast furnace matte, taken 22nd February, 1889, and the 2nd March, of the same year, showed copper 26·91 per cent and nickel 14·14 per cent. About the same time the Dominion Mineral Company produced mattes containing from 18 to 20 per cent copper and 24 to 26 per cent nickel. At the present time, however, this condition of affairs is reversed, and two specimens of this matte, analyzed by Mr. Donald Locke, of this Department, showed 14·53 per cent and 14·69 per cent of copper, with nickel 26·34 per cent and 28·17 per cent, respectively.

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(1) Eng. and Min. Jour., Dec. 2nd, 1893, Vol. LVI., p. 566.
(2) Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part F, p. 52.

The nickel present in the pyrrhotite of the Sudbury district varies usually from 2·25 per cent to 5·50 per cent, the lower figure being characteristic of such deposits as the Stobie, Murray and Elsie mines, while the latter is approached, and, at times, exceeded by the ore of the Creighton, Victoria, Blezard, Copper Cliff and Evans mines. Small specimens are occasionally met with which contain as high as 30 per cent of nickel, as at the Worthington mine, but such material is only obtainable by careful hand-picking, at either the Worthington or Creighton mines. These ores contain appreciable quantities of cobalt, gold, silver, and metals of the platinum group. Cobalt is almost invariably present, but in most of the assays of the ores which have been made, it is included with the nickel. The cobalt is usually very uniform in amount, in the proportion of 1 to 40 or 50 of the nickel present. The amounts of the rarer elements, such as gold, silver and platinum, are usually so small that the proportions of these can be best determined by analyses of the bessemer or higher grade mattes. Analyses of this product, which are available, containing about 80 per cent of combined nickel and copper, contain from 0·10 to 0·20 oz. of gold, with an average of probably about 0·15 oz. to the ton of 2,000 pounds, although L. P. Silver (1) obtained as high as 0·75 oz. of gold in the high grade matte of the Orford Copper Company, containing 39·64 per cent of nickel and cobalt, and 42·75 per cent of copper. Locke, of the Geological Survey, shows that in this same matte, containing 40·37 per cent of nickel and 24·95 per cent of copper, only 0·10 oz. of gold per ton is present. In the matte produced by the Mond Nickel Company, containing 41·88 per cent of nickel and 37·37 per cent of copper, this same chemist found 1/15 of an oz. of gold.

The silver in the ore is still more variable, as Locke found 2·5 oz. to the ton in the Orford Copper Company's matte, and 4·87 oz. to the ton in the matte produced by the Mond Nickel Company. J. W. Bain's (2) analysis shows 5·1 oz. to be present in the Orford Copper Company's matte. L. P. Silver shows that 5·30 oz. are present in each ton, while Ulké states that 7 oz. of silver are present in this same matte. The platinum, as already mentioned, is directly associated with the chalcopyrite, and, therefore, should be found in mattes which are relatively richer in copper. Locke found that the Orford matte contained 0·44 oz. per ton of metals of the platinum group, while the Mond Nickel Company's matte contains 0·4 oz. per ton of these same metals. Ulké mentions that the platinum and palladium, in about equal amounts, together made up about 0·50 oz. per ton, while L. P. Silver has secured the same result.

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(1) Jour. Can. Min. Inst., Vol. V., 1902, p. 534.
(2) Ann. Rep. Bur. of Mines, Ont., 1900, p. 218.

Nickel and Copper in Sudbury Ores.

—	Nickel.	Copper.	Total Nickel and Copper.	Authority.
	%	%	%	
1 Copper Cliff, Evans and Stobie mines.	2·38	6·44	8.82	Can. Copper Co.
1*a* Copper Cliff mine, average 1890.	3·69	6·24	9·93	"
2 Copper Cliff mine (mixed ore).	4·75	5·69	10·44	"
3 " (picked nickel ore)	8·12	0·80	8·92	"
4 " "	9·25	0·51	9·76	"
5 " "	11·00	0·00	11·00	"
6 " (picked copper ore)	2·74	14·13	16·87	"
7 " "	1·25	23·78	25·03	"
8 Evans mine (mixed ore)	4·00	2·60	6·60	"
8*a* Evans mine, average 1890	3·62	2·84	6·46	"
9 Evans mine (picked nickel ore)	5·36	0·49	5·85	"
10 " "	9·02	0·00	9·02	"
11 " (picked copper ore)	1·34	13·86	15·20	"
12 Stobie mine (mixed ore)	2·28	2·21	4·49	"
12*a* Stobie mine, average 1890	2·00	1·99	3·99	"
13 Stobie mine (picked nickel ore)	2·75	0·00	2·75	"
14 " "	2·99	0·37	3·36	"
15 " picked copper ore)	1·28	15·71	16·99	"
16 " "	0·64	24·23	24·87	"
17 No. 2 mine (picked nickel ore)	4·70	0·38	5·08	"
18 " (picked copper ore)	1·87	13·76	15·63	"
19 No. 2 Extension (picked ni. ore)	4·32	0·35	4·67	"
20 No. 3 mine (Frood mine) (picked nickel ore)	4·85	0·42	5·27	"
21 No. 4 mine	4·33	1·39	5·72	"
22 "	4·15	2·49	6·64	"
23 Creighton mine	7·03	1·81	8·84	"
24 "	4·87	1·20	6·07	Geol. Surv. Dept.
25 "	5·31	0·72	6·03	"
26 Victor mine	3·50	4·50	8·00	Mond Nickel Co.
27 "	3·05	3·05	6·25	"
28 "	2·67	2·81	5·48	"
39 "	3·21	2·41	5·62	"
30 Worthington mine	3·00	3·00	6·00	C. W. Dickson.
31 " (picked ni. ore).	17·48	0·00	17·48	T. L. Walker.
32 Blezard mine (metallic portion)	4·00	2·00	6·00	Dom. Min. Co.
33 Murray mine	1·50	0·75	2·25	H. H Vivian&Co

EXPLANATIONS.

1. Average of nine analyses, made by F. L. Sperry, of raw ore taken without selection from the Copper Cliff, Evans and Stobie mines, of the Canadian Copper Co., in November, 1888. 1*a*. Average of Cop-

per Cliff mine ore, for year 1890. (Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part F, p. 51.)

Analyses 2, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, are by David H. Browne, chemist to the Canadian Copper Company. (Eng. and Min. Jour., Dec. 2nd, 1893, p. 566.)

Analysis 8*a*. Average of Evans mine ore for the year 1890. (Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part F, p. 51.)

Analyses, 4, 7, 14, 16, 17, 18, 19, 20, 21, 22, 23 26, are from the catalogue of the mineral exhibit of Ontario at the Pan-American Exposition of 1901, pp. 33 and 35.

Analysis, 12 *a*. Average of Stobie mine for the year 1890. (Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part F., p. 51.)

Analysis 30 is the result of a number of analyses of average samples, by Mr. C. W. Dickson, (Trans. Am. Inst. Min. Eng., Albany meeting, Feby., 1903).

Analyses 24 and 25 are by Mr. Donald Locke, of the Geological Survey Department, Ottawa, of material obtained within a few feet of the surface.

Analysis 27 is the result of an average of a large number of assays of samples of raw ore, from the Victoria mines, as supplied to the smelter by T. M. Paris, the chemist. The insoluble amounted to an average of 16·81 per cent.

Analysis 28 is the average of the raw ore for July, 1902, by T. M. Paris, chemist to the Mond Nickel Company. Insoluble, 17·2 per cent.

Analysis 29 is the average of the raw ore for September, 1902, by T. M. Paris, chemist to the Mond Nickel Company. Insoluble, 13·9 per cent.

Analysis 30 is the result of an analysis of the pyrrhotite from the Worthington mine, which contained a large amount of pentlandite, by T. L. Walker. (Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part SS, p. 117.)

Analysis 32, according to Mr. George Attwood, manager for the Dominion Mineral Company, is the average of the results of many hundreds of assays of the 'kies' or metallic portion of the ore of the Blezard mine, also the practical working of the mine on a large scale. (Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part F, p. 52.)

Analysis 33 is the average percentage of the ore smelted at the Murray mine, according to Mr. F. R. W. Daw, the manager for Messrs. H. H. Vivian & Co. The 'kies' or metallic portion of the Murray mine ore contains on an average of about 2·75 per cent of nickel and 1·65 per cent of copper.

NICKEL AND COBALT IN ORES FROM SUDBURY DISTRICT.

Locality.	Insol.	Cu.	Ni.	Co.	Ni. in Metallic portion.	Authority.
	%	%	%	%	%	
1.—Location W. 7, (W. side Lake Wanapitei)......	40	Small quantity	2·00	None.	3·33	R. A. A. Johnston.
2.—Boucher's mine, N.E. side Lake Wanapitei......	25	Present.	1·57	"	2·09	" "
3.—Neelon township, Lot 12, Con. III	....	Small quantity	3·10	Trace.	3·10	" "
4.—Boundary line bet. Districts of Algoma & Nipissing, 2 miles N. of Lumsden tp ...	....	....	2·70	None.	2·70	F. G. Wait.
5.—Lorne township. Lot 2, Con. V	Small proportion.	Trifling amount.	1·95	"	....	R. A. A. Johnston.
6.—Lorne township	33	Small amount.	1·57	"	2·34	" "
7.—Nairn township Lots 1 and 2, Con. III........	Small proportion.	None.	1·95	Trace.	....	" "
8. — Drury township, Lot 3, Con. III......... ..	Trifling amount.	Little.	2·01	"	....	" "
9.—Denison township, Lot 6, Con. II.	12·5	None.	1·55	None	1·77	" "
10.—Levack township, Lot 7, Con. II	22	"	2·36	Trace.	3·02	" "
11.—Levack township, Lot 7, Con. II............	None.	"	4·13	None.	4·13	" "
12.—Levack township, Lot 3, Con. IV	18·5	Very small amount.	1·96	Trace.	2·40	" "
13.—Ross mine, W. R., 5, North Nickel range.......	16·5	Small amount.	2·75	None.	3·29	" "

Explanations.

1. Association of a somewhat coarse granular pyrrhotite with a small quantity of chalcopyrite, in greenstone.

2. An intimate association of chalcopyrite and pyrrhotite, in a gangue of greenstone.

3. A somewhat coarse granular pyrrhotite, associated with small quantities of chalcopyrite, from what was then known as the McCormick mine.

4. Pyrrhotite, in association with small quantities of dark-coloured greenstone.

5. Pyrrhotite, with a trifling amount of chalcopyrite, with greenstone.

6. Pyrrhotite, with a little chalcopyrite, with greenstone.

7. Pyrrhotite, with a small proportion of greenstone.

8. Pyrrhotite, with a little chalcopyrite, through which was disseminated a trifling amount of a quartzose gangue.

9. A somewhat coarse granular pyrrhotite, through which was disseminated a small amount of quartz.

10. A somewhat coarse granular pyrrhotite, through which was disseminated a quartzose gangue.

11. A very coarse granular pyrrhotite, free from gangue.

12. A somewhat coarse granular pyrrhotite, with a very small amount of chalcopyrite, in association with greenstone.

13. A coarse granular pyrrhotite, with a small amount of chalcopyrite. The gangue was readily discernible.

These analyses, 1 to 13, were done in the chemical laboratory of the Geological Survey Department, by Messrs. R. A. A. Johnston and F. G. Wait, assistants to Dr. G. C. Hoffmann. (Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part R., pp. 41-44 (Nos. 7 to 19).

THE SUDBURY PYRRHOTITE.

The composition of pyrrhotite, as shown by a large number of analyses, is not constant, and although repeated trials have been made by various chemists and mineralogists to obtain a formula which would be satisfactory, and representative of this mineral, their attempts so far have been attended with only a fair amount of success.

It has, therefore, been the custom to express the composition of pyrrhotite by the formula $Fe_n\ S_{n+1}$ the available analyses collected by Lindström in 1875, and by Habermehl in 1879, showing a variation of Fe: S = 1: 1., 1902, corresponding to $Fe_5\ S_6$, to 1: 1·0610, which agrees with the formula $Fe_{16}\ S_{17}$. Habermehl, from a mean of fourteen determinations, ten of which were essentially identical, showed that the Bodenmais pyrrhotite contains 60·57 per cent of iron, thus conforming closely to the formula $Fe_7\ S_8$, the theoretical composition of which would require 60·40 per cent of iron. This material was obtained on portions separated successively from the fine powder, suspended in water by a fine magnet. Doelter, by artificial means, produced a compound closely resembling, if not identical with the natural pyrrhotite, the analysis of which agreed with the formula Fe_{11} S_{12}.*

This variation in composition has suggested the possibility that pyrrhotite is not really a definite species, in a mineralogical sense, but rather a mixture, in varying proportions, of perhaps several closely related compounds. Such a view was regarded as also supported by the wide range in the specific gravity of the mineral, (3·98 to 4·80) as well as observed differences in the possession of certain physical properties, especially noticeable in regard to its magnetism. Some specimens exhibit this property in such a feeble manner that only the finer powder is attracted by the magnet, while others are so intensely magnetic as even to exhibit the phenomenon of polarity.

Careful consideration of all the facts available suggests that much, at least, of the discrepancies in composition can perhaps be better explained on other grounds. Thus, although it is known that a considerable number of these analyses were conducted on material which had been selected with great care, and using every known precaution to ensure a pure and homogeneous product, by far the larger number of determinations were of impure, often intermixed material. Besides, the methods of analysis were not always above reproach, so that errors constantly occurred, not only in the determination of the sulphur, but also of the iron. In addition, even with the possession of the requisite knowledge of analytical methods, as well as skill in their manipulation, it is usually extremely difficult, if not impossible, in all cases to obtain sufficiently homogeneous material on which to base a formula which would be thoroughly reliable and representative. If we regard pyrrhotite as a sulphide, intermediate in chemical composition between the normal sulphide FeS and the disulphide FeS_2, it is possible to obtain every gradation of material showing a range in the iron content from 63·61 per cent to 46·60 per cent, while the sulphur to correspond would show a gradual increase from 36·39 per cent to 53·40 per cent. There is, however, a wide gap between Fe_7 S_8 with iron 60·40 per cent and sulphur 39·60 per cent, and Fe S^2 with iron 46·60 per cent and sulphur 53·40 per cent. These analyses, however, which have evidently been conducted with the greatest care, show a variation in formula from Fe_{11} S_{12} with iron 61·60 per cent and sulphur 38·40 per cent, to Fe_7 S_8 with iron 60·40 per cent and sulphur 39·60 per cent. These determinations are as uniform and accurate as could be expected from material so manifestly impure as pyrrhotite.

A satisfactory and reliable analysis of Sudbury pyrrhotite is, perhaps. more than usually difficult to obtain, owing to the very intimate association of various closely related sulphides. In the first place, it was the generally accepted view that the nickel really replaced isomorphously an equivalent amount of iron, and was thus an essential constituent of the pyrrhotite, whereas it is now a well ascertained fact that by far the greater proportion of the nickel, at least, occurs as a distinct and separable nickel-iron sulphide. Many, however, still cling to the belief, that a small portion of the nickel may exist in a state of chemical combination, but such persons can find little support for this view in the fact, that, by repeated use of a magnetic separator and with material sufficiently comminuted, it is possible to remove almost the last trace of nickel from a compound which originally contained from 2 to 5 per cent of this element, while the isolated nickel-iron-sulphide or pentlandite is usually pure enough for analytical purposes. The process is, however, tedious, and repeated trials are necessary before the pyrrhotite or pentlandite is obtained of the degree of purity desired.

In addition, other sulphides, mainly chalcopyrite, but sometimes also pyrite, are present, the former almost invariably accompanying the pyrrhotite, and all of these are so intermixed with one another that very fine grinding and the assistance of magnetism is necessary before a satisfactory and complete separation can be effected. Such a dissociation, however, may be conducted at the same time as the trials for the elimination of the pentlandite are proceeding, while this latter mineral, which is itself feebly magnetic, can, in turn, be separated from the copper and iron pyrites, which do not possess the property of magnetism in any sensible degree. The chief difficulty, however, encountered in the purification of the pyrrhotite, arises from the fact that a small quantity of magnetite ($Fe_3 O_4$), often amounting to not less than 1 per cent of the whole, is almost invariably present. C. W. Dickson, after a number of experiments, found, that by treating the sample with dilute (10 per cent) solution of nitric acid, the pyrrhotite could be largely removed, while the magnetite was but little affected. The separated sulphur was removed by means of bromine and carbon-bisulphide; and, after several treatments, the residue of magnetite was obtained pure, and the iron was estimated by titration. The nature of these operations, as he remarks, involves the possibility of some loss, especially as the amount of magnetite is comparatively small, but, on the whole, the method answered very well. The greater number of the analyses indicated that the pyrrhotite could be represented by the formula $Fe_8 S_9$, while two or three others worked out to $Fe_7 S_8$ and $Fe_9 S_{10}$. The first-mentioned formula may be regarded as the most probable for the pyrrhotite from the Sudbury district. He likewise mentions the interesting fact that a trial of a specimen from Rossland, B.C., showed it to be represented by the same formula ($Fe_8 S_9$).

The pyrrhotite is always massive and amorphous, showing all gradations of texture from very finely to very coarsely granular, the coarser varieties possessing well marked cleavages in two directions. As may be seen by a reference to the analyses there is little or no foundation for the popular belief that the coarsely crystalline varieties are relatively poorer in nickel than those which are finer grained. Good crystals are extremely rare, and although occasional fragments are found which are apparently bounded by crystal faces, such planes are really the direct result of cleavage. Perhaps the only authenticated crystal of pyrrhotite was obtained by Mr. G. R. Mickle, from a man working in the Worthington mine. Mr. Mickle thus describes it: 'The crystal is evidently a hexagonal prism showing strongly marked basal cleavage; two of the sides are intact, and portions of two others remain. The dimensions are $1\frac{5}{16}$ inches, or 32mm., by ½ inch, or 13mm.; the weight, 27·4 grains; and an analysis of a very small fragment from the crystal gave 2·3 per cent of nickel.'

The colour of the pyrrhotite is a bright steel-grey on fresh fracture, quickly weathering to a deep bronze-yellow, often, however, tarnished or iridescent.

CHALCOPYRITE.

The copper contained in the ore is all obtained from chalcopyrite, the common sulphide of copper and iron, ($CuFeS_2$ sulphur 35·0 per cent, copper 34·5 per cent, iron 30·5 per cent = 100·0). It is always massive, with the usual deep brass or yellow colour. As usual, this mineral is very subject to tarnish, and beautiful iridescent specimens can be obtained from the ore heaps, or scattered around the works. The composition of the ore varies greatly, as may be seen by a reference to the analyses, and according to the preponderance of either the pyrrhotite or chalcopyrite, the resulting furnace product or matte is relatively richer or poorer in nickel or copper. The mines of the Canadian Copper Company, as the name implies, were first operated for their copper contents, and it was not until considerable work had been done that nickel was discovered to be present in the ore. A large shipment of ore had been made to New York, and a chemist there who was making a volumetric determination of the copper contents, by the potassium cyanide process, was struck by the great variation in his results, which led him to make a more minute examination of the ore, when he found that nickel was present. The ore has now become of more value on account of its nickel than its copper contents, and Dr. Peters himself greatly doubted if the mines would pay to work for copper alone.

NICKEL AND COBALT IN SUDBURY PYRRHOTITES.

Locality.	Insol.	Cu.	Ni.	Co.	S.	Iron.	Ni. in pure Pyrrhotite.
	%	%	%	%	%	%	
1. Elsie mine (a)......	2·00	Trace.	2·40	0·06	......	...	2·46
2. „ (b)........	3·45	„	2·35	0·05	......	.....	2·44
3. Stobie mine (a)......	1·50	„	3·00	0·08	......	......	3·05
4. „ (b).......	4·00	„	2·05	0·05	......	......	2·15
5. No. 3 mine (a)......	0·40	„	2·35	0·05	...	...	2·40
6. „ 3 „ (b)......	5·00	„	2·34	0·06	...	......	2·48
7. Mount Nickel.......	2·20	„	3·00	0·07	......	.....	3·06
8. Copper Cliff No. 4 mine (a)....	1·10	„	3·24	0·06	......	......	3·30
9. Copper Cliff No. 2 mine (b)...............	5·00	„	3·70	0·08	......	......	4·00
10. Copper Cliff No. 5 mine (c)................	0·50	„	3·47	0·08	......	.....	3·50
11. Creighton mine (a)...	3·25	„	3·84	0·10	......	......	4·00
12. „ (b)...	0·50	„	2·26	0·06	.....	....	2·32
13. Gertrude mine (a)....	5·00	„	3·83	0·11	......	......	4·05
14. „ (b)....	6·00	„	3·61	0.09	.. .	.....	4·00
15. Victoria mine (a).....	0·50	„	3·36	0·07	......	....	3·40
16. „ (b).....	0·40	„	3·14	0·08	......	......	3·20
16a. „ (b).....	3·00	4·50	3·50	....	32·00	55·00	....
17. Levack township.....	3·20	Trace.	2·80	.....	......	......	2·88
18. Wisner „	4·10	„	2·22	......	......	......	2·32
19. Creighton mine (a)...	2·28	0·72	5·31	......	34·28	......	....
20. „ (b)...	2·49	1·20	4·87	......	34·62	......	....
21. Copper Cliff (7th level) (a)....	......	0·00	11·00	......	38·01	50·40	11·00
22. Copper Cliff (7th level) (b)......	......	0·00	4·62	......	38·58	55·70	4·62
23. Stobie mine (a).......	......	0·00	2·75	......	35·35	58·00	2·75
24. „ (b).......	.....	0·00	2·15	... .	36·10	57·00	2·15
25. Evans mine (a).......	.....	Trace.	9·02	......	39·28	51·50	9·02
26. „ (b).......	......	0·00	3·82	....	40·18	56·00	3·82
27. Copper Cliff mine ..	7·75	Trace.	3·40	0·175	......	......	Co=0·2, Ni 3·98
28. Cryderman mine....	2·96	„	4·46	0·174	......	......	Co=0·18, Ni 4·6
29. Cochrane mine. ...	11·10	0·10	3·52	0·146	......	....	Co=0·16, Ni 3·90
30. Little Stobie mine...	2·70	Trace.	4·06	0·165	......	......	Co=0·17, Ni 4·17

EXPLANATIONS.

Analyses 1-18, inclusive, with the exception of 16a, were made by Mr. C. W. Dickson, (Trans. Amer. Inst. Min. Eng., Albany meeting. Feb., 1903) in duplicate or triplicate, to ensure the greatest possible accuracy. These were made to ascertain as accurately as possible the average nickel and cobalt contents of the general run of the pyrrhotite from the whole region. The pyrrhotite was coarsely crushed, and the mineral picked out as pure as possible, under a lens, when necessary. From the massive varieties good samples were easily obtained, but, in other cases, the pyrrhotite was so intimately mixed with chalcopyrite and rock that it was very difficult to obtain satisfactory samples, some rock always adhering to the sulphide. The results obtained show that the percentage is fairly constant over a wide area. The pyrrhotite includes both fine and coarse-grained. In the case of the coarse-grained varieties, where the nickel mineral pentlandite can often be recognized, this was carefully rejected, as far as possible. But the difficulty of separation accounts for the fact that some of these varieties show less nickel than the finer-grained ones, although the former are usually considerably richer. Had the coarse-grained samples been treated in their original condition the results would have been more uniform. These analyses, therefore, represent the nickel which is most intimately associated with the pyrrhotite and does not appear as particles of pentlandite.

1. Coarse pyrrhotite, with a small amount of chalcopyrite and rock; 2. Compact fine-grained pyrrhotite, with a small amount of rock; 3. Massive, fine-grained pyrrhotite; 4. Pyrrhotite and chalcopyrite, in diorite; 5. Pure, coarse pyrrhotite; 6. Fine-grained pyrrhotite; 7. Massive pyrrhotite; 8. Coarse pyrrhotite; 9. Massive, fine-grained pyrrhotite; 10. Massive, fine-grained pyrrhotite; 11. Massive, fine-grained pyrrhotite; 12. Coarse pyrrhotite; 13. Massive pyrrhotite; 14. Massive pyrrhotite; 15. Massive, fine-grained pyrrhotite; 16. Coarser than No. 15, but with more chalcopyrite; 16a. Analysis of ore by Mond Nickel Company; 17. Massive pyrrhotite (Tough & Stobie's property); 18. Coarse, massive pyrrhotite, from the Northern Nickel range; 19 and 20 are analyses by Mr. Donald Locke. Analyses 21 to 26, inclusive, are of ore selected for purposes of magnetic concentration, by Mr. David H. Browne. Analyses 27 to 30, inclusive, are by Mr. M. F. Connor, of this Department, and were of hand-picked ore, as free as possible from chalcopyrite and gangue. All of the specimens were of pyrrhotite of medium grain, with the exception of that from the Little Stobie mine, which was a very coarse cleavable variety.

MODE OF OCCURRENCE OF THE SUDBURY NICKEL DEPOSITS.

Most geologists, at least, who have examined these deposits in detail, are agreed that they are not true fissure veins, and although at times certain sloping surfaces are obtained, which seem to have a uniform inclination and limit the distribution of ore in their direction, yet it seems certain that there are no regular walls, in the miner's sense of the term, and at both sides of the deposit the enclosing rock is impregnated, more or less, with pyritous matter. Although mining is thus rendered somewhat difficult and uncertain, on account of the absence of the walls, and irregularity in the distribution of the ore, so that there is very little means of knowing in what direction to drive the levels, this uncertainty is usually more than compensated by the extent and massiveness of the deposits, when found.

The ore-bodies are of irregular, oval or pod-shaped outline, and all agree in having their longer axes to correspond very closely with the direction of the foliation of the enclosing rocks. The shapes and dimensions of the ore-bodies of the International Nickel Company's mines at Copper Cliff are accurately shown on the accompanying large scale maps. There are three main types of these ore deposits in the Sudbury mining district.

1. Those which occur at the southern border of the immense body of hypersthene-gabbro, or norite, which reaches without interruption from Drury to Garson townships. Under this division are included the Gertrude, Creighton, North Star, Tam O'Shanter, Lady Violet, Elsie, Murray, Cameron, Little Stobie, Mount Nickel, Blezard, Beatrice, Kirkwood and Cryderman mines.

2. Those which are developed in connexion with offsets or dike-like forms of the norite, extending southward from the main mass, and which are intruded into the older rocks, almost at right angles to the planes of foliation and bedding. This would embrace such mines as the Victoria, Clarabelle (No. 6), No. 4, Lady Macdonald (No. 5) and No. 2, and the extensions of No. 2 mine.

3. Those which are associated with smaller and, at present, completely isolated bodies of norite. These separate masses of the nickel bearing eruptive are so closely identical, in mineralogical composition, structure and behaviour, to the parent eruptive, that they are probably connected with it, in some way, at a distance below the surface.

The original Copper Cliff, No. 1, and its extensions, Evans, Frood (No. 3) and Stobie mines are all examples of this last-mentioned class.

The first-mentioned divisions of deposits are all situated at the immediate contact between this huge mass and the older rocks, into which it is intruded. The intrusive nature of this contact is well shown, the impregnation of the old green schists consisting, for the most part, of small, dike-like forms or veins of sulphide material, injected along the planes of schistosity, while, on the other side, the line of separation between the ore-body and the norite is even more uncertain, the sulphide material gradually fading out, until it is only represented by occasional disseminations. To the northwest this basic rock shows a gradual differentiation or passage into the peculiar and characteristic type of gneissic granite usually referred to as 'micropegmatite.' On the Levack or Middle range (Windy Lake eruptive), this condition of affairs is reversed, and we find the deposits at the northwestern margin of the norite, while its differentiate, the micropegmatite, lies to the southeast. This same condition of affairs obtains on the Northern Nickel range where the norite comes in contact with the older granites and green schists on the north side, while the micropegmatite underlies the area to the south.

The Worthington and the Vermilion mines are the only deposits which have been developed, having no visible connexion with the main mass of norite already noticed. As has been shown on a previous page, the Worthington mine occurs on a narrow neck of actinolite diorite, which is, without doubt, the altered representative of the older norite. To the southwest and east this norite is directly connected with a much larger mass of basic eruptive material. As far as can be learned no large deposit of ore was encountered at the Vermilion mine, and the small amount of norite found resembles very closely the decomposed variety of the older type of this rock.

Rounded hills of gossan, indicating the presence of the more or less pure and unaltered ore beneath, extend with almost unbroken continuity for miles along the line of junction, while by far the larger portions of the offsets and isolated masses with which the ore-bodies are associated are also of a prevailing brownish colour, from the decomposition of the abundantly disseminated sulphides. This gossan has resulted, as usual, from the alteration of the pyrrhotite and chalcopyrite, and the formation of hydrous oxide of iron, which gives a prevailing brownish colour to the upper portions of the deposits. This covering of iron oxide is sometimes as much as six feet in depth, although usually it is only two or three feet, gradually merging into the unaltered ore beneath. The depth to which this gossan extends depends largely, of course, on the length of time the deposits have been uncovered, and thus exposed to processes of weathering. Some, from which the green forest and overlying soil have but lately been removed, show little or no iron oxide, while others, like the Murray mine, which have been exposed to the action of the weather for years, exhibit an extensive covering of this characteristic decomposition product. From the Elsie mine, in a northeasterly direction, past the Murray mine as far as the boundary between McKim and Blezard townships, a considerable belt of rock occurs at the immediate margin of the norite, so heavily charged with sulphides that its weathered outcrop at the surface is covered with this gossan. At the old Copper Cliff mine, as well as at the Creighton mine, this overlying gossan is very wide spread and deeply impressive.

In most cases these ore-bodies show a brecciated character, large angular or partially rounded blocks of almost barren rock being mingled with the ore. Some of these horses, as they have been called, are made up of the material derived from the wall rock against which the pyritous matter cooled. Their presence, in this connexion, is no doubt due to the shattering of the invaded formation at their contact with the plutonic magma. In fact, they form an illustration, on a small scale, of the phenomenon of 'overhead stoping,' so fully described and explained by Dr. R. A. Daly.(1) In other instances, however, this comparatively barren material is of norite, but such inclusions are seldom sharply defined from the sulphide, exposures showing a gradual transition from one to the other, while the blocks themselves are generally more or less plentifully impregnated with the prevailing sulphide.

No great depth has yet been reached by the workings of any of the mines of the marginal type of deposits. The deepest of the shafts is at the Blezard mine, which has only been sunk a distance of 172 feet, while those of the Murray and Gertrude are 160 and 120 feet deep, respectively. On the other hand the diamond drilling undertaken at the Creighton is stated to have proved the existence of this phenomenally large body of nickle ore to a depth of at least 400 feet. This wonderful deposit of pyrrhotite has been worked, mainly, as a large open pit, measuring 150 by 200 feet, and extending to a depth of 62 feet. All of these deposits dip to the north and northwest at an angle varying from 30° to 70°.

Of the mines belonging to the second group of those developed along the offsets, the two most important are the Victoria mine and the No. 2 mine, of the International Nickel Co., at Copper Cliff. The Victoria mine, of the Mond Nickel Company, with seven levels and extensive slopes, has reached a depth of 557 feet. The No. 2 mine has afforded a large amount of ore, being worked for the most part as a large open pit, measuring about 250 feet in length, by 100 to 150 feet in width, and with a depth of 217 feet.

The original and famous Copper Cliff mine has often been referred to as a chimney of ore, averaging in width from 50 to 100 feet in the cross section, through the shaft, while at right angles to this direction it varies from 30 to 210 feet The first or old haft, now in large part abandoned except for pumping purposes, was sunk to a depth of over 500 feet, on an incline of 40°, while shaft No. 2, or the new shaft to take its place, starts from the third level, at a distance of 150 feet from the surface, and continues at an angle of 77° 30′, or approximately parallel to the ore body, to the 14th level (depth 1,058 feet).

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(1) Amer. Jour. Sc., Vol. XVI., 1903, p. 108.

The ore body of the Stobie mine, developed in connexion with a small isolated mass of norite, has an inclination of 65°, and, although the workings have only reached a vertical depth of 250 feet, it has yielded a larger amount of ore than any other mine in the district (415,000 tons).

ORIGIN OF THE ORE DEPOSITS.

The question as to how these abnormally large masses of sulphide material acquired their present position and dimensions has furnished a fruitful topic for speculation and discussion ever since their first discovery. Fortunately, however, only two theories, with some minor modifications, have been advanced in explanation of the manner of their formation, and which may be summarized as follows:—

1. That the sulphides are directly of igneous origin, the products of the differentiation of a gabbro or norite magma, being segregated along its margin in obedience to Sòret's principle, the order of formation of the minerals being in accordance with Fournet's series.

2. That these ore bodies are altogether of secondary and aqueous origin, occurring as replacements along crushed and faulted zones.

The extreme advocates of either theory seek to ignore the share of the other in forming these deposits, as they exist at present. Thus, those who originally held that these ores were the immediate product of magmatic segregation failed to mention, or at least emphasize the possibility that those deposits were, in any way, influenced by the presence of these heated solutions, which to a certain extent accompany, and in all cases immediately follow all plutonic action. On the other hand those who consider these deposits as of secondary origin, in seeking to explain the source of the metals, although they acknowledge as a fact, 'that the universal association of these ores with essentially similar rocks is also striking' and again 'that the norite, (or gabbro) has an intimate connexion with the development of the ores cannot be doubted, but in just what way they are related is not clear,' still at the same time they nullify any effect which might be produced by such information by a statement to the effect, that 'an appeal must be made to a more distant source of the metals, probably minutely disseminated in the rocks through which the depositing solution passed.' (¹)

The writer, who was one of the first to affirm a direct igneous origin for these Sudbury ores, giving independent expression to precisely similar views, which about the same time were stated, in much more detail, by Professor J. H. L. Vogt, of Christiania, Norway, realizes the fact that, in the first endeavour to fix definitely the responsibility for these unusual occurrences, too much emphasis was perhaps given to the idea of magmatic differentiation, as in itself giving an adequate explanation of all the phenomena witnessed. This can only be excused on the ground that this doctrine as applied to ore deposits was an entire innovation, and its strongest affirmation was at first very necessary in order to effect its recognition as a previously ignored though important factor in the development of ore deposits. More recent and detailed examination of the various ore bodies has shown that while the first hypothesis of a segregation of these sulphides, directly from the magma, is, in the main, the true explanation of their present position, other agencies, which are usually grouped together under the name of secondary action, have contributed rather largely to bring about their unusual dimensions.

As Professor Kemp remarks, (²) 'increasing experience leads us to look with especial favour on the igneous rocks as the original source of the ore, whose widely disseminated, although, when considered in comparison with their mass, whose small percentages of all the metals, except the invariably abundant iron, suggest to us original stores for leaching. We are also attracted to them, as a source, because, without doubt, all other rocks must be ascribed to them in the last analysis; because they are so often in close association with ores as mined, and because, above all, they are the natural stimulators of those heated solutions to which we can with most reason attribute the results.'

At the present day, fused magmas are regarded as more or less complex solutions, which, by reason of their high temperatures, obey the same laws in the order and method of their solidification as those which govern the crystallization from ordinary solutions of a similarly heterogeneous composition. A study of thin sections of igneous rocks, under the microscope, reveals the fact that a certain definite order in the generation of the component minerals is always obtained, which is closely followed in the cooling of any body of magma. Thus, in a gabbro or norite magma, the oxides of iron and

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(1) Trans. Amer. Inst. Min. Eng. Albany Meeting, Feb., 1903.
(2) Min. Industry, Vol. IV., 1895, pp. 756-757.

titanium, the sulphides of iron, nickel and copper, zircon and apatite are the first to crystallize. These are followed by the ferromagnesian silicates, olivine, hypersthene, biotite and diallage. The plagioclase may antedate, accompany or immediately follow the crystallization of one or more of the coloured constituents, depending on its basicity, while quartz is invariably the last to form, filling up all the irregular interspaces remaining. One of the main laws governing the crystallization from a solution, or an igneous magma, is known as Soret's principal, according to which the dissolved matter is concentrated in the coolest part of the solution. Gravity, temperature and pressure are also important factors, but these have not yet been deeply investigated.

Perhaps one of the most significant developments of modern petrographic geology has been the recognition of the fact that an originally homogeneous molten mass tends to so separate or split itself, upon cooling, as to ultimately produce rocks of varying composition. This fact, bearing so intimately on the genesis of igneous rocks, has caused the formulation of the hypothesis known as magmatic differentiation. The hypothesis may be briefly described as the division or differentiation of a more or less viscous magma, or fused mass of rock, into chemically and mineralogically diverse parts, which, on cooling, yield correspondingly different types of rocks. It would be manifestly unwise in this connexion to enter into any detailed explanation of this very generally accepted hypothesis, as the conditions attending the consolidation of a large body of magma are now believed to be much more complex than at first supposed. Moreover, our knowledge regarding these conditions, and the several processes which are no doubt involved, is so vague and incomplete that no full or satisfactory explanation can yet be offered of this phenomenon. All geologists of repute are, however, agreed on the main fact that magmatic differentiation furnishes the only reasonable explanation of most of the observations made in connexion with any extended exposure of igneous rocks.

Applying these principles to the geological relations of the Sudbury gabbro or norite, and the associated sulphide deposits, the subjoined facts seem to furnish unanswerable proof that the hypothesis of a segregation of these ore bodies, directly from the magma, is, in the main, the true explanation of their position.

1. The deposits, without exception, all occur at the margin of the gabbro or norite, the rock itself in immediate association with the ore being finer in texture, and relatively much more basic in composition than portions further removed from the contact. There is a very gradual increase in the basicity of the gabbro outward from

the micropegmatite, although a rather abrupt transition takes place in the immediate neighbourhood of the contact. The sulphides are also finer grained near the contact, while farther away they become coarser grained. (1)

2. The sulphides are always much more sharply defined against the walls of the intrusion than on the inner side towards the main mass of the gabbro, the transition in this direction showing a more gradual decrease in the amount of ore in the rock as the contacts are left. This phenomenon, as has been mentioned, is explained by the fact that the sulphides, in obedience to Soret's principle, become concentrated towards the cooling surface of the mass.

3. These deposits are always found in such intimate association with the norite or hypersthene-gabbro that we are forced to the conclusion that the ore bodies stand in some genetic relation to this plutonic igneous rock. This is not only true in regard to the Sudbury district, but is also the invariable association of precisely similar deposits, found in Norway, Sweden, Lombardy and Pennsylvania. The importance of geological studies, in connexion with ore deposits, is emphasized by the fact, mentioned by Adams, (2) that although, in these several widely separated countries, the pyrrhotite deposits, associated in the manner described with the gabbros, are so rich in nickel, the celebrated Fahlbands of Norway, which are bedded, or apparently bedded, deposits, consisting of heavy impregnations of pyrrhotite, pyrite, chalcopyrite, etc., but occurring in gneisses and schists of various kinds, contain hardly any nickel, hundreds of analyses showing the nickel and cobalt contents to range from 0·1 to 0·5 per cent, and what is still more remarkable the same is true of the similar Fahlbands associated with our Laurentian in Canada, so far as these have been examined. In these the pyrrhotite and pyrite is present in large amount, and is often associated with copper pyrites, but only a very small quantity of nickel and cobalt, ranging from faint traces to 0·16 per cent, occurs in the pure sulphide material. In addition, pyrrhotite, chalcopyrite and pyrite occur, sometimes in promising quantities, in the older green schists and tuffs of the Sudbury district, but even the richest of these deposits were shown by analyses to contain a much smaller amount of nickel, ranging from 0·45 to 0·96 per cent, in the pure pyrrhotite.

4. Pyrrhotite, chalcopyrite and pyrites are all ordinary constituent materials of the normal norite, and are, at times, comparatively abundant even in exposures situated some distance from the contact.

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(1) Quart. Jour. Geol. Soc., Lon., Vol. LIII., 1897, p. 52.

(2) 'On the Igneous Origin of Certain Ore Deposits,' Montreal, 1894, p. 17; also, Ann. Rep. Geol. Surv., Can., Vol. VI., 1892-93, Part J.

We may readily obtain, at any of the mines, specimens which exhibit every gradation in the amount of these sulphides present in the rock, from the ordinary type of norite, with occasional disseminated grains of the pyritous matter, to what has been referred to by Vogt as 'pyrrhotite-gabbro or norite' with from 5 per cent to 50 per cent, or even 80 per cent of pyrrhotite, while portions of some of the deposits are made of practically pure pyrrhotite and chalcopyrite, with little or no gangue matter.

5. The sulphides are, undoubtedly, of primary origin, and are among the earliest of the minerals to crystallize out from the original magma, sometimes even antedating the iron ore, in which they are occasionally completely enclosed. They occur in very much the same way as the iron ore, embedded in, or in the immediate vicinity of the various coloured constituents. In fact individual grains can only be distinguished from one another by their colour in reflected light. This intimate association between the iron ore not only occurs in the normal norite, but even the ore bodies themselves, especially those of the North range, which almost invariably contain titaniferous magnetite often in appreciable quantities. Occasionally considerable masses of magnetite, sometimes several tons in weight, are encountered in the working of the mines, which are completely enclosed in the sulphide material, while this iron ore itself contains disseminated grains of the pyrites, in addition to certain decomposed silicates belonging to the norite. The relations which obtain between the sulphides and the norite are closely analogous to deposits of magnetite, occurring in connexion with certain basic igneous rocks in central Ontario. In these deposits the magnetite is the abundant ore, while the sulphides are usually present in subordinate amount. The enclosing rocks usually show much more alteration than in the case of the norite associated with the Sudbury sulphide deposits.

6. The transitional type between the normal norite and the richer forms of the pyrrhotite-norite furnishes unmistakeable evidence that, in these cases at least, the sulphides were formed during the cooling and crystallization of the norite magma, and that they were very little affected by any secondary action. The only effects of pneumatolytic or vein action noticed, consisted in the more or less complete alteration of the pyroxene minerals, while much of the plagioclase is surprisingly fresh and glassy. Although most of the rock matter associated with the ore bodies is more or less decomposed the alteration is not of the extreme type, which would be expected if the whole of the deposits resulted from secondary action. The writer's collection of rocks contains specimens of the pyrrhotite-norite, sometimes containing as high as 10 per cent of the sulphides, from most of the

principal mines, which are so free from alteration as to permit of the precise identification of both the orthorhombic and monoclinic pyroxenes. The rocks in the immediate vicinity of the ore bodies are not, therefore, as generally described, so made up of secondary minerals as to thoroughly obscure their original composition and structure, but, on the contrary, the least altered representatives of the norite may readily be obtained at or in the immediate vicinity of any of the mines.

7. Fournet has shown that sulphur, when dissolved in a molten magma of silicates, shows affinity for the metals in the following order: copper, nickel, cobalt, iron, tin, zinc, lead, silver, antimony and arsenic. The small percentages of copper, nickel and cobalt present in the original magma unite with the sulphur, and thus become concentrated in any sulphide of iron which separates, while any tin, zinc, lead, silver, antimony or arsenic present in the magma is not so concentrated.

8. Vogt (1) mentions that if we were to distribute the whole metallic contents of the ore deposits through their respective mother rocks in Norway these would have the following percentages: nickel, 0·03 per cent to 0·12 per cent; cobalt, 0·005 per cent to 0·017 per cent; and copper, 0·015 per cent to 0·05 per cent. No attempt has been made to calculate these percentages, with regard to the Sudbury district, but the above results are just about what would be expected from our knowledge of the nickel contents, generally, in the basic silicates of rocks.

9. One difficulty which has often been urged against the direct development of these deposits from a state of igneous fusion is that it would be impossible to obtain such large and comparatively pure concentrations of the sulphides. Mr. David Browne (2) has shown by numerous analyses and diagrams that in a pot of matte the nickel tends to concentrate towards the centre, while the copper is much richer at the outer margins. This is exactly the experience in mining. 'These observations,' Prof. Kemp remarks, 'are extremely important, showing as they do the migration of metallic matter even in so viscous and quickly chilling a mass as a pot of matte.'

10. Vogt believes that eruptive magmas may keep dissolved even very considerable quantities of sulphides, supporting his belief by the fact that basic blast furnace slags usually hold from 3 to 5 per cent of sulphides, especially CaS and MnS; likewise, the basic ferriferous slags from copper, nickel and lead smelting may contain from

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(1) Min. Industry, Vol. IV., 1895 p. 748.

(2) School of Mines Quarterly, Columbia College, July, 1895, p. 297; also Min. Industry, Vol. IV., 1895, p. 762.

4 to 6 per cent FeS and the basic zinc slags even 6 to 8 per cent ZnS. Sandberger separated the dark silicates of many rocks and proved them to contain copper, nickel, cobalt, lead, tin, antimony, arsenic, bismuth and silver.

11. Galena, zinc blende, and compounds of arsenic and bismuth are either completely wanting or present in very insignificant amount.

12. The remarkable scarcity of boracic and fluoric minerals and other secondary products which usually attend any pronounced or long continued vein action.

13. Secondary quartz, calcite and dolomite are occasionally present, in appreciable amounts, but the prevailing scarcity of these minerals, at most of the deposits, has always been a subject of remark, and the first mentioned mineral has often been brought from considerable distances, not only to line the converters, but also to add to the furnace charges, even at such mines as the Victoria, where secondary quartz is relatively perhaps more abundant than at any other deposit in the district.

14. Platinum, usually at least, in the form of sperrylite, is found in small quantities at all of the deposits. Such an occurrence seems to be closely related to the native platinum and osmiridium metals, in the altered basic olivine rocks of the Urals and elsewhere.

15. The deposits are singularly uniform in chemical and mineralogical composition, and their monotonous character, in this respect, has been frequently commented upon. A careful study of the analyses will serve to further emphasize this fact. This peculiarity holds good, not only with regard to the Sudbury deposits, but applies with equal force to those of Norway and elsewhere, wherever full details of composition are available. The characteristic minerals of this 'world group,' as it has been called, are everywhere the same. Pyrrhotite, with generally from 2 to 4 per cent of nickel and cobalt, although occasionally reaching as high as 10 to 11 per cent of nickel, pyrite (in Norway relatively rich in cobalt), pentlandite, together with some chalcopyrite, and some titaniferous magnetite, are always present in the norite or gabbro. The nickel minerals polydymite, millerite, etc., are also often present, but only in very subordinate amounts.

16. Brecciation, which is so frequently characteristic of these deposits, is an almost constant feature of eruptive contacts, resulting from the detaching of material from the containing walls. The frequent angular character of these blocks is due to their imperfect assimilation by the fused basic magma, in which they have been floated off.

These are some of the main points which may be urged in support of the hypothesis of magmatic differentiation, as explanatory of the origin of these Sudbury ore deposits. Many of them are not new, and have been stated in more detail by Vogt, Adams, Kemp and others. They are introduced, in the present instance, as the trend of some of the more recent examinations seeks to ignore the full significance of the intimate genetic relationship which exists between the norite and the ore bodies, affirming that secondary causes or replacement are alone and directly responsible for the present position and dimensions of these deposits.

Vogt, (1) in his classification of eruptive ore deposits, divides them into two chief groups. 1. Deposits formed by 'magmatic differentiation'; that is by the concentration of some metallic parts within the still fluid eruptive magma. 2. Deposits formed by processes subsequent to the eruption or 'after actions,' as they have been sometimes called;—that is by pneumatolysis, fumarole action, hydrothermal agents and the like, directly consequent on the eruption.

The trend of modern geological investigation seems to emphasize, more and more, the fact that no really sharp division exists, as indicated by Vogt's sub-divisions, but that processes, which at the two extremes are manifestly very widely divergent in their effects, are so intimately associated in time and manner of operation in nature, that the resultant product cannot, with any degree of propriety, be attributed wholly to either group of processes.

Thus, although the researches of M. Fouqué and Michel-Lèvy have clearly shown that diabase and kindred basic eruptive rocks may be artificially reproduced from a simple state of dry fusion, it is equally certain that no extended intrusive process, produced by natural causes, is ever unaccompanied by a greater or less abundance of superheated waters and vapours, as an integral portion of the fused mass. As a general rule these heated solutions are relatively much more abundant in the case of the acidic magmas than those of more basic composition. It is thus obvious that all igneous action is both accompanied and, in a more extended manner, immediately followed by more or less pronounced vein or pneumatolytic action (secondary causes) and certain rocks and mineral occurrences may be representative of the various transitions between what has been termed aqueo-igneous fusion and igneo-aqueous solution. The abnormally large amount of original or primary quartz, so uniformly distributed throughout the Sudbury norite or gabbro, has been repeatedly mentioned and commented upon by the various geologists who have examined these rocks in detail under the microscope. It thus naturally follows that the agencies grouped together under the name of secondary action would be much more actively effective in connexion with the ore bodies and other segregations resulting from the eruption of such a rock, than with the ordinarily less quartzose or basic varieties of such rocks. The manner of formation of these ore bodies, as thus indicated, is much more complex than was at first supposed. There can be no doubt, however, that much of the sulphide material was introduced simultaneously, as an integral portion of the same magma, along with the other minerals of which the norite or hypersthene-gabbro is composed. There can, moreover, be little doubt of the abundant presence of heated solutions and vapours which were capable of dissolving out, and, under certain conditions, of redepositing these sulphides. Such agencies certainly began their work before the whole magma had cooled, bearing their heavy burdens of sulphide material, most of which was obtained from the magma in the immediate vicinity, to occupy the various cavities and fissures as fast as these were formed. The whole of this action was practically completed before the intrusion of the later dikes of the olivine-diabase which are now regarded by the writer as the end product of the vulcanism to which the norite masses owe their intrusion. In certain of the deposits the various hydrochemical agencies accompanying dynamic action have been more active than in others, as at the Victoria mine, and some of the Copper Cliff mines, but in others, as for instance the Creighton mine, magmatic differentiation has been the main and almost sole principle, determining and favouring the development of this the largest and richest sulphide nickel mine in the world. The enunciation, in the first place, of the simple doctrine of the direct igneous origin of these ore bodies and their intimate relationship in this respect to certain bands of norite or diorite, served an excellent practical purpose in directing and controlling all the earlier prospecting work.

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(1) Zeit für Prak. Geol. 1893, pp. 4-11; 125-143; 257-284; also 1895, pp. 145-156; 367-370; 444-459; 465-484.

After all, however, the origin of these ore deposits is largely a matter of theory and opinion, and strong arguments may be adduced in support either of the view that they are the direct result of magmatic segregation, or that the sulphides were brought up in a state of solution from considerable depths, to replace certain portions of the rock, or to fill up spaces caused by structural weakness. The real practical side of the geological investigation consisted in the outlining of the immense masses of intrusive norite or gabbro, with which the nickel and copper deposits of the region are alone associated.

MAGNETIC SEPARATION OF NICKELIFEROUS PYRRHOTITE.

The application of magnetism, either to free the pyrrhotite from impurities with which it is so frequently intermixed, in order to obtain a homeogeneous and pure product for analytical purposes, as well as to effect a separation of the nickel present in the pyrrhotite ores, is by no means a novel idea, and many experiments have already been undertaken with this end in view. In 1879 Habermehl succeeded in dividing the Bodenmais pyrrhotite into magnetic and non-magnetic portions respectively, using fine powder suspended in water by a strong magnet. The magnetic portion thus separated by successive trials furnished a product which was so homogeneous and uniform that ten out of fourteen of the determinations for iron content were essentially identical.

In 1890, T. J. McTighe (¹) applied magnetic separation in the treatment of the nickeliferous pyrrhotite of Canada.

In July, 1892, Mr. Thomas A. Edison, in applying for a United States patent embodying the same principle, gave the following explanation in support of his claim:—'I have discovered that when magnetic pyrites, called "pyrrhotite" is nickeliferous, as it usually is to a more or less extent, the nickel is distributed generally throughout the whole body of the pyrrhotite, but certain crystals are pure pyrrhotite or magnetic pyrites, while other crystals have some of the iron replaced by nickel and sometimes by cobalt, and that the crystals containing the nickel or cobalt are considerably less magnetic than the pure pyrrhotite.'

In the same year (1892), Dr. S. H. Emmons (²) carried on certain magnetic experiments on material obtained from the Gap mine, Penna., and Sudbury, Ont. These were undertaken not only for the purpose of testing the accuracy, or otherwise, of the theory of the replacement of a portion of the iron by nickel in pyrrhotite, but also to arrive at a more accurate expression of the composition of pyrrhotite, by means of a formula. The practical side of the question was not ignored, and a statement of the relative abundance of the separated portions is given, with their respective contents of nickel.

Dr. Emmons mentions that he obtained his material from a mine near Sudbury, but does not specify the precise locality. He also neglects to give the necessary details of the composition of the ore selected, except that the gangue formed 10·7 per cent of the whole. In regard to the preparation of the material for purposes of separa-

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(1) Ann. Rep. Bur. of Mines, Ont., 1892, p. 164; also Jour. Am. Chem. Soc., Vol. XIV., No. 10.

(2) Ann. Rep. of Mines, Ont., 1892, pp. 163-166; also Jour. Am. Chem. Soc., Vol. XIV., No. 10.

tion, he states that the sample was very finely powdered and carefully separated by means of a magnet into three grades, namely, 'magnetic,' 'feebly magnetic' and 'non-magnetic.' The magnetic and non-magnetic grades were then submitted to analysis, resulting as follows, after deduction of gangue.

Magnetic.	Analysis.	Feebly Magnetic.	Non-Magnetic.	Analysis.	Division of total nickel contents.		
					Magnetic portion.	Feebly magnetic.	Non-magnetic.
92·95%	Ni 1·30	2·09%	4·96%	23·16	58·01%	7·60%	34·39%
	Fe 58·27			33·92			
	S 40·43			42·92			

A short time after, (1893) David H. Browne (1) contributed the most valuable article on the question of the magnetic separation of these ores which had yet appeared, showing the existence of a rich nickel-iron-sulphide, almost identical in chemical composition with pentlandite, which formed the non-magnetic portion of the separation. In the same article Mr. Browne questions not only the validity of Dr. Emmons' conclusions, as 'hasty generalizations from insufficient premises,' but points out that 'he has never yet found the non-magnetic residue of the analysis given by Dr. Emmons.'

The material selected for experimental purposes by Mr. Browne consisted of carefully hand-picked nickeliferous pyrrhotite from the Copper Cliff, Stobie and Evans mines, altogether free from gangue, and with no copper, or, at the most, only traces of this metal. He mentions that the samples were crushed to pass a sixty-mesh sieve, experiment having shown that a very fine powder did not yield such perfect separations. The following tables show, in brief form, the results obtained:—

COPPER CLIFF MINE, (SEVENTH LEVEL.) PICKED NICKEL ORE.

Analysis of total ore.	Magnetic.	Analysis.	Non-magnetic.	Analysis.	Nickel in magnetic pyrrhotite.	Nickel in non-magnetic pentlandite.
Cu.......... 0·00	78·6%	0·00	21·4%	0·00	34·00%	66·00%
Ni.......... 11·00		4·62		35·05		
Fe.......... 50·40		55·70		29·80		
S.......... 38·01		38·58		34·35		

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(1) 'Engineering and Mining Journal,' Dec 2, 1893, page 566.

STOBIE MINE, PICKED NICKEL ORE.

Cu.......... 0·00	97·175%	0·00	2·825%	0·00	72·00%	28·00%
Ni.......... 2·75		2·15		34·70		
Fe ....58·00		57·00		29·90		
S.............35·35		36·10		33·90		

EVANS MINE, PICKED NICKEL ORE.

Cu..........trace	84·04%	0·00	15·96%	0·00	35·47%	64·53%
Ni.......... 9·02		3·82		34·12		
Fe..........51·50		56·00		29·95		
S.............39·28		40·18		35·43		

In 1900, Mr. J. N. Judson, of the Wetherill Separating Company, carried on an extensive series of experiments, an abstract of the results accompanying Mr. C. W. Dickson's paper on 'The Ore Deposits of Sudbury, Ontario.' (1) The material experimented with consisted of nearly pure pyrrhotite from Copper Cliff, containing by analysis nickel 3·14, copper 0·42, iron 49·78 per cent. The results showed that with a current strength of one ampère, on material crushed to thirty-mesh, 90·11 per cent of the total sample was magnetic, and this contained 2·46 per cent of nickel, or the equivalent of 70·58 per cent of the total nickel in the original pyrrhotite, and 0·22 per cent copper, or the equivalent of 47·48 per cent of the total amount of this metal in the original sample. The remaining, non-magnetic portion, forming 9·89 per cent of the total sample, contained 9·33 per cent nickel and 2·21 per cent copper, or 29·42 per cent and 52·52 per cent of the total of these metals, respectively, in the original sample. The other trials, with samples of the same material, crushed to pass a sixty-mesh at ¼ ampère, showed 86·22 per cent was magnetic and contained 1·92 per cent of nickel. The remaining 13·78 per cent, or non-magnetic portion, was a comparatively rich nickel ore, but the losses in the magnetic portion were so great that Mr.Judson concluded that a commercial separation, by means of magnetism, was out of the question.

During the winter sessions of 1901-1902, and 1902-1903, Mr. C. W. Dickson, a post-graduate student at Columbia University, carried on a series of experiments, by means of magnetism, in order to determine, as near as possible, how much of the nickel occurs as a separate mineral, and how much, if any, replaces iron, and also to ascertain the composition of the nickel mineral.

A number of representative samples of pyrrhotite were ground to pass through a 100-mesh, and the non-magnetic portion was removed, as completely as possible, by repeated treatments with a small horseshoe magnet. The nickel present in the original samples is given under I, and that of the magnetic concentrates under II.

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(1) Trans. Amer. Inst. Min. Eng. (Albany Meeting), 1903.

In the second treatment the original samples were coarsely crushed and the magnetic portion was seized between forty and sixty-mesh, then freed, as well as possible, from non-magnetic material, crushed between sixty and eighty-mesh, and again concentrated. By successive treatments the mineral was finally reduced to fine powder. The ultimate product was then assayed for nickel, and as shown under III, the nickel was much reduced in quality, but not entirely eliminated.

In the third experiment, to see if it was possible to still further reduce the nickel contents, a number of samples were very carefully prepared. They were coarsely crushed, and the purest mineral selected.

This was crushed to pass through ten on twenty-mesh, and the finest material rejected. All the non-magnetic portion was eliminated, and the concentrate was then crushed to twenty on forty-mesh, the inner part being again rejected. The operations were repeated until the ore was finally removed each time. The nickel in the final concentrate is given under IV.

Location.	I. Ni and Co.	II. Ni.	III. Ni.	IV. Ni.	Description of sample.
1. Elsie mine	2·44	2·22	0·98	...	Fine-grained pyrrhotite.
2. Stobie mine	3·05	2·14	0·68	.....	" " "
3. Frood mine	2·40	2·07	1·05	0·65	Coarse " "
4. Mount Nickel mine	3·06	2·14	0·75	0·70	Medium " "
5. Copper Cliff No. 2 mine	4·00	2·00	0·70	......	Coarse " "
6. Copper Cliff No. 4 mine	3·30	2·32	0·83	.....	" " "
7. (a) Creighton mine	2·32	2·25	1·20	0·70	" " "
7. (b) Creighton mine	4·15	......	.....	0·45	Fine " "
8. Gertrude mine	4·00	2·30	1·10	....	Massive pyrrhotite.
9. Victoria mine	3·40	2·46	0·80	.....	Fine-grained pyrrhotite.

As stated by Mr. Dickson the results show in the most conclusive manner that even in the lower grades of pyrrhotite the nickel is not present, as replacing part of the iron in the pyrrhotite, but exists as a separate mineral. The fact that all the nickel could not be eliminated by the methods used did not indicate that even the small amount that remained was an essential part of the pyrrhotite, as several factors entered which rendered its complete removal practically impossible. In the first place the nickel mineral is very intimately associated with the magnetic pyrrhotite, and even a minute adhering fragment of the latter will cause it to be carried over with the magnetic portion. It must also be noted that the nickel mineral itself is slightly magnetic, and in the form of a fine powder is attracted by even a small magnet.

The magnetic experiments in connexion with the present work were carried on by Mr. W. M. Ogilvie, B.A. Sc., by means of a Wetherill magnetic separator of the ordinary type, in the mining laboratories of McGill University, the authorities, with the recommendation and approval of Dr. J. B. Porter, having kindly placed the machine at the disposal of the writer for a considerable period during the winter of 1901-1902. The samples selected consisted of the richer grades of ore in use at the different mines. Such samples were obtained from the Creighton, Victoria, Cryderman and Mount Nickel mines, the Tough and Stobie property, in Levack township, and the Cochrane property, near Blue lake, on the Northern Nickel range. It is to be regretted that the chemical analyses could not be undertaken while the experiments were in progress, as otherwise much more important results could have been obtained. The voltage of the current employed was 110, and the strength of the current was varied according to the magnetic permeability of the different samples. The least magnetic of the material was that obtained from the Creighton mine, and with such material a current as high as 15 ampères was employed, while the pyrrhotite from the Cochrane property, on the Northern Nickel range, was so strongly magnetic that much weaker currents had to be used, the greatest reaching a strength of only 1·5 ampères.

In the case of the Creighton mine the original sample weighing thirty-six pounds was divided into two products, according to the size of grain obtained by crushing. The first product was obtained by passing the powdered mineral through a forty-mesh sieve, and catching it on a 100-mesh sieve, this part weighing twenty-one pounds. The second product, fifteen pounds, was made up of the finer material which passed through the 100-mesh sieve. The coarser phase of the original sample gave the following analysis: Insoluble, 2·28; copper, 0·72; nickel, 5·31, and sulphur, 34·28 per cent. The composition of the finer material was: Insoluble, 2·49; copper, 1·20; nickel, 4·87, and sulphur, 34·67. Each of these two original samples was divided into three equal portions, and subjected to magnetic currents of 1·5, 3·8 and 15 ampères respectively. By means of the magnetic current each of these three portions was again subdivided into three grades, which may be designated as 'magnetic,' 'feebly magnetic' and 'non-magnetic.' The coarser material showed that the magnetic portion varied from 86·3 to 90·2 per cent of the whole sample, with a loss of 2·4 to 9·7 per cent in handling, which loss, however, could be overcome, while the feebly magnetic portion contained from 4·2 to 8·6 per cent, and the non-magnetic from 1·2 to 2·7 per cent. In the finer material the magnetic portions varied from 74·6 to 78·3 per cent, the feebly magnetic from 2·3 to 10·9 per cent, while the non-magnetic varied from 4·1 to 8 per cent. The loss in the case of the fines was very great, owing to the dust adhering to the belts, the percentages of such loss varying from 9·2 to 11·4 per cent. Assays of all the separate products from the Creighton mine were made by Mr. Donald Locke, who for a short time was attached to this Department as assayer and metallurgist, but certain unexplained discrepancies in the results will prevent, at present, the publication of all the details of the chemical investigation. In this connexion, however, it may be sufficient to state that a very rich nickel ore was always obtained, the greater part of which was contained in the feebly magnetic portion, although a small proportion was carried over into the tailings or non-magnetic portion. The loss, however, in the magnetic portion, amounting to from 40 to over 50 per cent of the total nickel present in the original ore, was too serious to be disregarded. In addition to the nickel present the magnetic part also contained from 28 to 48 per cent of the total amount of copper present in the original ore, while from 16 to 18 per cent is contained in the feebly magnetic part, and the remainder is carried over with a large proportion of the gangue into the non-magnetic residue, which is really a very rich copper concentrate, some of the assays showing as high as 28·38 per cent of this metal. The proportion of gangue present in the non-magnetic residue generally amounts to about one-third of the total product.

The best separation is effected on the fine material, although the presence of dust must be avoided, as this clings to and fouls the belts. The stronger the current the greater the proportion of nickel remaining in the magnetic portion, while, at the same time, although the total amount of nickel present in the feebly and non-magnetic portions is less, the assay value of such products is much higher, and some of these, which were examined in detail, consisted almost wholly of pentlandite, with intermixed chalcopyrite. Thus, the feebly magnetic product of the fine material, obtained by using a current of 3·9 ampères with only one trial, showed, on analysis, the following composition: Insoluble, 5·81; copper, 1·52; iron, 30·41; nickel, 30·01, and sulphur, 33·56 per cent. Knowing the composition of the pentlandite and chalcopyrite, and distributing the above constituents in their proper proportions in these materials, we find that this product consists of chalcopyrite and pentlandite in the ratio of 1:21. In the same way the non-magnetic product obtained by using a current of 1·5 ampères on this fine material and from which most of the gangue had been removed by means of hydraulic separation, showed, by analysis, the following composition: Insoluble, 2·66; copper, 3·58; iron, 30·01; nickel, 30·36, and sulphur, 33·77 per cent. This product is made up of chalcopyrite and pentlandite in the proportion of 1:7.

In the Victoria mine's separation the ore was much more strongly magnetic, and the currents employed were only 0·2 and 1·5 ampères. The magnetic portion varied from 86·4 to 90·6 per cent on the coarser material, while with the fine material, using a current of 0·2 and 1·2 ampères, the magnetic part varied from 71·4 to 86·7 per cent. The feebly magnetic part never exceeded 2·1 per cent, and in one case was as low as 0·5 per cent. No assays of these products, however, have been made, as the results obtained in the case of the Creighton mine, although of great scientific and practical interest, demonstrated rather clearly that under present conditions an economic and commercial separation of these ores is out of the question.

The Cryderman mine ore is also more magnetic than the Creighton, although less so than the Victoria. The original sample on which the experiment was conducted weighed thirty pounds. This was divided into two portions, according to size, one portion consisting of crushed ore which passed through a forty-mesh and was caught on a 100-mesh sieve, and finer material consisting of ore which passed through the 100-mesh sieve. The currents used had a strength of 0·2, 1·5 and 4 ampères respectively. The magnetic portion of the coarser product varied from 75 to 85·6 per cent, the feeble magnetic from 2 to 7·7 per cent and the non-magnetic from 1·9 to 2·3 per cent. There was no loss using the 0·2 and 1·5 ampères current, but with the 4 ampères current the loss was 4·8 per cent. With the finer material the magnetic part varied from 65·6 to 71·8 per cent, although the loss of 10·9 per cent belongs very largely to the first mentioned amount. The feebly magnetic part varied from 1·6 per cent to 17·2 per cent, the latter amount being obtained with the 4 ampères current, while the non-magnetic varied from 6·3 to 28·1 per cent.

The magnetic separation of the ore from the Nickel Mountain mine was effected by using currents having a strength of 1·5, 3·8 and 13·5 ampères respectively. The original sample weighed sixty-three pounds. The magnetic part of the coarser product (through forty-mesh on 100-mesh) varied from 91·2 to 92·5 per cent with losses of 0·9 and 2·5 per cent respectively, the feebly magnetic from 4·1 to 4·4 per cent, and the non-magnetic from 1·2 to 3·8 per cent. The losses varied from 4 to 5·7 per cent, and are accounted for by the fact that the fine material has a great tendency to stick to the belts. Also the cross belts were given their maximum velocity to effect the best separation.

The original sample from the Levack property (Tough and Stobie's), weighing twenty-four pounds, was crushed in the same way as the above, and the magnetic currents used had a strength respectively of 0·2, 1·5 and 3·8 ampères. The magnetic portion varied from 92·5 to 96·3 per cent, with losses belonging chiefly to this part of 1·9 to 2·5 per cent, the feebly magnetic from 1·3 to 3·8 per cent and the non-magnetic from 1·3 to 2·5 per cent. With the fine product, the magnetic portion varied from 91·6 to 93·8, with a loss in one instance of 1·9 per cent, the feebly magnetic from 1·1 to 2·1 per cent, and the non-magnetic from 5·2 to 6·3 per cent.

The pyrrhotite from the Cochrane property on the Northern Nickel range is very strongly magnetic, and the current used had a strength of 0·2 and 1·5 ampères. The magnetic portion of the coarser product varied from 85·3 to 89 per cent, with a loss of 1·4 to 2·8 per cent, the feebly magnetic 1 to 4·8 per cent, and the non-magnetic from 4·8 to 10·9 per cent. With the finer material the magnetic portion varied from 77·7 to 83 per cent, the feebly magnetic from 0·8 to 4·1 per cent and the non-magnetic from 15·2 to 18·2 per cent.

The various factors which enter into the construction of the Wetherill magnetic separator suggested, at the outset, that by its employment it might be possible to accomplish a separation on a commercial basis, which, at the same time, would be much more thorough and complete than any previously recorded attempts, making use of different types of hand magnets. Thus, it was possible on this machine not only to vary at will the strength of the magnetic current to be used, but also to make any required adjustment in the distance between the two magnets, while, at the same time, the speed of the belts was under complete control. With these refinements or aids to efficient separation it was hoped to make such a thorough division of the products that the nickel present in the magnetic portion would constitute so small a proportion of the whole as to render this product of no commercial value, and thus, at one simple operation, get rid of about 80 per cent of practically barren ore. At the same time, it was believed that the feebly and non-magnetic portions would contain by far the larger proportion of both the nickel and copper.

The preliminary trials of the Creighton mine ore and assays of the separated products were disappointing, as they showed most conclusively that an efficient and economical separation by this method was impossible. It was, therefore, considered unwise to analyze the products from the other mines, although the main facts in connexion with these separations have been mentioned.

About the same time Mr. C. W. Dickson published the results of his magnetic experiments, which gave further emphasis to this conclusion. Mr. Dickson's final utterance on this subject, published in 1903, also contained a summary of Mr. J. N. Judson's results, to which reference has already been made, all tending to show that the removal on a commercial scale of the nickel from the pyrrhotite, by magnetic methods, is, in the light of our present experience, an impossibility. On the other hand, the fact that all of the nickel cannot be eliminated from the pyrrhotite does not prove that even the portion remaining occurs as a replacement of an equal amount of iron in chemical combination. Examination under the microscope reveals the fact that even the smallest grains of sulphide material are often made up of intricate intergrowths of chalcopyrite and pyrrhotite, which minerals, moreover, can be distinguished from one another by the use of reflected light. Such an intimate relationship, doubtless, obtains in the case of the pyrrhotite and pentlandite, although this could not be proved, as these minerals cannot be separately recognized under the microscope. In addition, a large proportion at least of the pentlandite is itself feebly magnetic, and this is apt to remain with the pyrrhotite.

The difficulty of obtaining an absolutely pure product, even of minerals of widely different magnetic permeability, is well known to all who have carried on experiments in magnetic separation, so that it is not surprising that the magnetic portion of the separated sulphide always contains an appreciable amount of nickel. In the light of our present experience it is safe to say that the nickel is doubtless present as very minute grains of pentlandite embedded in or adhering to the grains of pyrrhotite. The fact that material originally containing 5·31 per cent of nickel, with the application of a current of 1·5 ampères on material crushed to pass only through a forty-mesh sieve can, at one operation, be separated into a magnetic product containing only 1·48 per cent of nickel, while this, in turn, by successive grinding and magnetic treatment can be ultimately forced to give a product which contains less than 0·50 per cent of nickel, is in itself sufficient evidence for regarding all the nickel in these Sudbury ores as occurring in the form of a distinct sulphide, chiefly pentlandite. With all of the foregoing results we may well pause and repeat with Dickson the question, 'Is there such a thing as a true nickeliferous pyrrhotite?' and we might even extend it and ask, is there such a thing as a true nickeliferous pyrite? The matter is still open for further investigation, although at the present stage the *onus probandi* rests with those chemists and mineralogists who are still wedded to the old idea. A most convincing proof might be possible, by repeated magnetic treatment of some of the masses of pyrrhotite occurring in central Ontario, which are known to contain from 0·05 to 0·23 per cent of nickel. Any enrichment of the feebly magnetic or non-magnetic product obtained from the separation of such material would no doubt furnish the most ample proof, which even the most skeptical would be forced to accept.

LOCATION OF PYRRHOTITE DEPOSITS BY MAGNETOMETRIC MEASUREMENTS.

The magnetic permeability of pyrrhotite early suggested the employment of magnetic instruments to determine the location of valuable deposits of this nickel bearing sulphide in the Sudbury district. All the earlier measurements, however, were made by means of the ordinary dip-needle, and the observers were content to obtain such data as would enable them to form a rough judgment of the approximate area underlaid by rock containing more or less of the magnetic pyrrhotite, although this mineral might be so sparsely disseminated as to be of no economic importance.

In 1901, however, it was decided by the Mond Nickel Company to inaugurate a more extensive and elaborate system of magnetic surveying, not only in examining the properties they had already purchased, but also in determining the probable value of other nickel properties which were known to be in the market. It was realized that such delicate instruments as the Thalen-Tiberg magnetometer. in the hands of experts who had been trained in the Swedish methods, would yield data in regard to the location and extent of workable deposits of pyrrhotite which would enable a very close estimate to be formed of their commercial value. Early in the spring of 1901, Messrs. Karl Köjer and Erik Nyström, mining engineers of Stockholm, Sweden, and pupils of the well known Professor Nordenström, were engaged. Mr. Köjer only stayed about a month, but Mr. Nyström was employed for the greater portions of the two seasons of 1901 and 1902 in making detailed magnetic surveys of various mining locations and mines in this district. Most of the lots in the vicinity of the main shaft of the Victoria mines were thus minutely examined, and later other properties such as the Murray, Lady Violet, Mount Nickel, Beatrice and Cryderman mines were also similarly treated. A magnetic survey was also made of the Cochrane property on the Northern Nickel range. It is impossible to get the details of the results of this work, as the maps which were prepared with great care are the property of the Mond Nickel Company, the information being regarded as of a confidential nature.

The value of such work, however, when properly undertaken, is beyond all doubt, although considerably more care and expense is necessary than is the case with magnetite. Speaking roughly, the magnetic permeability of magnetite is about five times as great as pyrrhotite, although this latter mineral varies very greatly in this respect. It is, therefore, imperative, that the lines along which the magnetic observations are made should be correspondingly closer together. In most of the detailed work undertaken by the Mond Nickel Company these lines were only separated by intervals of twenty feet, while in some special cases, where fuller information was desired or necessary, a distance of only ten feet intervened between the various observation stations. For some time, commencing in 1902, Mr. Thomas A. Edison carried on rather extensive magnetic surveying in the area between Sudbury and Wanapitei lake, with a view of discovering new deposits of nickel ore. The efforts of the several parties engaged in this work are stated to have met with a considerable degree of success, as on the strength of the information obtained various mining locations were applied for. Messrs. J. A. Robert and G. F. Kay have also conducted magnetic surveys under the auspices of the Lake Superior Power Company. The publication of Dr. Haanel's report (1) 'On the Location and Examination of Magnetic Ore Deposits by Magnetometric Measurements' should stimulate this method of inquiry, not only in connexion with these pyrrhotite deposits, but also as regards our magnetic iron deposits. It is the only detailed account of the Swedish method which has yet appeared in the English language. With the exception of magnetic observations to assist in the geological mapping, chiefly of the iron formations and associated rocks of the Lake Superior district, details of which are furnished by Prof. H. L. Smyth (1), no very extensive use of magnetic instruments has been made in any other country outside of Sweden. The Swedish instruments may be obtained from J. Fr. Berg, instrument maker, Stockholm, and are the most perfect and suitable for the work which have yet been manufactured. All necessary descriptions and information in regard to their operation may be obtained by consulting Dr. Haanel's work, which he hopes may be of service to the mining profession.

CLASSIFICATION AND GENESIS OF NICKEL ORES.

Mineralogically the ores of nickel may be divided into eight classes, as follows: 1. Sulphides; 2. Arsenides and sulph-arsenides; 3. Sulph-antimonides; 4. Sulpho-bismuthides; 5. Tellurides; 6. Silicates; 7. Oxides and Salts; 8. Carbonates.

Many of the nickel minerals included under these divisions are unimportant in an economic sense, and Vogt (²) has shown that all of those which are commercially valuable fall naturally into three main groups.

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(1) Published by the Department of the Interior, Ottawa, Canada.

(1) Trans. Amer. Inst. Min. Eng., Vol. XXVI., pp. 640-709.

1. Ores containing arsenic and antimony, with or without bismuth, such as niccolite, gersdorffite, chloanthite, &c.

2. Sulphide ores (without arsenic), as for example, nickeliferous pyrrhotite and pyrite, pentlandite, polydymite, millerite, &c.

3. Silicated nickel ores, such as genthite, garnierite, &c.

The arsenides and sulph-arsenides, belonging to the first group, occur principally in veins, as for instance the old and well known metalliferous lodes of Saxony and Hungary; Mine la Motte and Bonne Terre, in Missouri; the Gem mine in Fremont county, Colorado; the McConnell or Gersdorffite mine, in the Sudbury district, Ontario; and the recently discovered deposits near Haileybury, on the west side of Lake Timiskaming, Ontario.

By far the largest deposits, belonging to the second group, are the nickel-copper sulphide ores of the Sudbury district, in Canada, which are the subject of the present bulletin, but Norway has, for many years, operated on a large scale precisely similar concentrations. Other closely related ore bodies have also been worked as mines, as at Varallo, in Piedmont, Italy, and at Lancaster Gap in Pennsylvania. The deposits which have been partially developed and worked near St. Stephen in the province of New Brunswick, Canada, are also apparently of the same nature. The most celebrated and extensive of the deposits, representative of the third group, are those of New Caledonia. Important bodies, however, of similar silicates are known to occur, and have been developed to some extent, near Riddle's, in Douglas county, Oregon, and near Webster, the capital of Jackson county, in western North Carolina.

The veins of the first group occur either penetrating or in intimate connexion with eruptive rocks of the peridotite or gabbro type, and are generally found in the more decomposed or altered portions. These basic igneous rocks, as is well known, contain appreciable quantities of nickel as a normal constituent. The extremely rich nickel ore contained in these veins has, therefore, evidently been derived from the leaching out of the nickel from the neighbouring rock during certain processes of alteration to which it has been subjected.

The method of formation of the sulphide deposits of the second group, typified by the Sudbury deposits, has already been discussed at length, and the conclusion reached that they are the direct product

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(2) Zeit fur Prak. Geol., 1893..

of the differentiation of a basic igneous magma, modified, to some extent, by processes which are usually grouped together under the designation of secondary action.

The silicates ot nickel are always confined to areas underlaid by intrusive masses of non-feldspathic basic magnesian rocks of the peridotite family, the several varietal forms of which are distinguished from one another by the names of dunite, saxonite, websterite and eherzolite. These rocks are always more or less decomposed to a serpentinous material, so that the type of rock with which these deposits occur is usually described as serpentine.

The ore rarely crops out at the surface, but is covered with a thick mantle of decomposed material, from which most, if not all, of the nickel has been leached, to be concentrated in places a few feet lower down. This covering or soil is very highly ferruginous, with occasional large 'chert' fragments lying about. These pseudo-boulders of so-called chert are considered a favourable sign in prospecting for the ore bodies, for they invariably indicate the presence of the peridotite beneath. They really represent residual portions of the peridotite, which escaped the wholesale decomposition on account of their being held together by an intricate series of quartz veinlets, the interstices of which are occupied by only partially decomposed peridotite. The surface mantle or soil usually varies from nothing up to a few feet when it gives place, gradually, to a loose, brownish material, representing the decomposition of the peridotite 'in situ.' This usually shows abundant, but small and intricate veins and veinlets of the greenish silicate of nickel and magnesium, often with abundant scales of chrome mica. In places irregular fissures and cavities, often of considerable size, are occupied by rather pure silicate material. This brownish, loose material gives place, in turn, to a brownish, soft, friable rock, filled with smaller but harder and rich veinlets of the nickel silicate, while this, again, is replaced farther down by the unaltered peridotite, which, it is believed, will contain little or none of the silicate concentrations.

Analyses of the associated dunite or websterite, from the North Carolina occurrences, show the undecomposed rock to contain from 0·15 to 0·35 per cent of nickel oxide, while the saxonite, in which the Oregon occurrences are developed, contains, according to Diller, 0·10 per cent of nickel oxide, while the olivine itself, of which the rock is mainly composed, contains 0·26 per cent of nickel oxide. This is a very unusual occurrence, and the undecomposed peridotite of New Caledonia often contains as high as 1 per cent of nickel oxide. Similar rocks, from the Eastern townships of Canada, show the presence of 0·15 to 0·26 per cent of oxide of nickel, without cobalt, while the associated chromic iron ore also contains 0·22 per cent of oxide of nickel, with distinct traces of cobalt. It is almost impossible to collect any of the brownish material, resulting from the decomposition of these peridotites, without finding an appreciable amount of nickel present. It appears certain, therefore, that the nickel has been leached out of the surrounding rock, and redeposited along with silica and magnesia in all available cracks and interspaces. The peridotite is always readily decomposed under ordinary conditions of atmospheric decay, the magnesia being the first ingredient to be carried away in the form of a carbonate. This is followed by the silica and nickel, which is redeposited at lower levels and in suitable places. The result of such an origin will be the occurrence at these several localities mentioned of comparatively shallow deposits, their downward extension depending almost entirely on the depth to which decomposition has proceeded. On the other hand, the ease with which many of these deposits may be mined, and the large amount of comparatively rich and desirable nickel ore which may be thus secured, make them particularly attractive.

DISTRIBUTION OF NICKEL ORES.

Ores of nickel are much more evenly and abundantly distributed over the whole world than is generally supposed, but in only a few countries are the deposits of such dimensions as to warrant their development as working mines, and, at the present day, the mines of New Caledonia, and those of Sudbury produce almost the whole of the world's supply of nickel.

Small quantities of the arsenides and sulph-arsenides of nickel are found in association with ores of silver, lead, bismuth and cobalt, in the well known veins of Saxony and Hungary. As a rule, however, this nickel may be regarded as a by-product obtained in the refining of these ores, and although valuable, it forms a comparatively small proportion in comparison with the other metals present.

Nickel also occurs in Sweden and Finland, and the famous deposits of Norway for many years produced a comparatively large proportion of the nickel of the world. Nickel is also known to occur in Scotland, while the serpentines of the west of Ireland, and those of Cornwall, all contain a little nickel associated with them.

In Russia, nickel has been reported from Rewdinsk and Zanghesour. The most celebrated deposit of nickel in the United States is at the Gap mine, in Lancaster co., Pennsylvania, but this mine suspended operations in 1891. The domestic production of nickel in the United States is, at present, all derived as a by-product from the treatment of lead ores, which are found in the mineralized portion of the sedimentary limestones at Mine la Motte, Missouri. Very rich nickel ore has been found in the 'Gem mine' in Fremont co., Colorado. Nickel minerals are also known to occur at other localities in this state, as for example in the hornblendic rock near Salida, associated with copper, and also in small quantities in some of the ores from the Leadville region. The occurrence of nickel has also been reported from several places in California. At the Kelsey mine, in Los Angeles county, nickel and cobalt are found in the form of arsenates, together with silver-glance and native silver, in a fissure vein in close relation with a dike rock, probably diorite. The associated ores contain 7 to 15 per cent cobalt, and 2 to 3 per cent nickel, and 1,000 to 1,400 ounces of silver per ton. (1) Nickel also occurs at the cobalt mines near Chatham, Connecticut. Some important bodies are known to exist in Nevada but these have not been extensively developed. Nickel ores are also reported from Idaho, Arizona and New Mexico. Rich ores of nickel also occur in the copper district south of Lake Superior. The most important deposits of nickel ore at present known to exist in the United States are the silicates of North Carolina and Oregon, to which more detailed references will be made.

In Canada the distribution of the nickel deposits occurring at Sudbury have already been described, but important bodies of similar sulphide material are also known to occur, and have undergone preliminary development at St. Stephen, New Brunswick. Other occurrences are reported from British Columbia and the province of Quebec, but these are at present of no economic importance. In Newfoundland rich nickel ore has been found in considerable quantities at the Union mine, at Tilt cove in Notre Dame bay. Australia, New Zealand, South Africa and Chili all contain deposits of nickel ore, but New Caledonia is the only formidable rival with which Sudbury has at present to deal.

NICKEL IN CANADA.

The Wallace mine, about a mile west of the mouth of the Whitefish river, on the north shore of Lake Huron, is of historic interest, as being the first place in which the presence of nickel was recognized in Canada. It was first opened as a copper mine, in 1847. During the season of 1848 this location was visited by Mr. Alex. Murray, Assistant Provincial Geologist, who reported on the geological associations and probable extent of the deposit. (1) This occurrence has also been described by Mr. C. W. Dickson (2), as consisting of pyrrhotite, pyrite and chalcopyrite, occurring at the junction of two small dikes of mica-diorite which are intruded into the surrounding quartzites. The mining development work undertaken did not reveal any large body of ore, and although a considerable amount of copper ore was encountered, in association with a rich arsenical ore of nickel, the occurrence of the latter in very small veins, adjacent to the southern wall of the mine, did not encourage extensive mining operations, and the mine was accordingly soon abandoned. The material obtained by Murray, in 1848, was handed to Dr. Hunt for analysis. This specimen, weighing forty-five ounces, is described by Dr. Hunt as 'a steel grey arseniuret, the species of which I have not yet determined, with iron pyrites and probably some arsenical sulphuret of iron.' The analysis of the whole mass, when powdered, gave the results under I. The first five substances, making 59·30 per cent of the ore, are separated, as corresponding to the metallic portion of the mass, although it is probable that a portion of the iron is derived from the gangue. The cobalt equals about three parts in a thousand of the weight of the nickel. Removing the gangue, and recalculating the remainder to 100, we get the results under II.

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(1) Proc. Col. Sci. Soc., Vol. IV., 1891-93, pp. 419-20.

	I		II
Iron	24·78		41·79
Nickel (with a trace of cobalt)	8·26		13·93
Arsenic (mean of two determinations)	3·57		6·02
Sulphur	22·63		38·16
Copper	0·06		0·10
		59·30	100·00
Silica	28·40		
Carbonate of lime	4·00		
Magnesia	4·40		
Alumina	3·21		
		40·01	
		99·31	

Two ores of nickel are described by Dr. Hunt (3) as occurring 'in a vein cutting a bed of amygdaloid, on Michipicoten island, in

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(1) Rep. of Progress, Geol. Surv., Can., 1848-49, pp. 42-45; also pp. 61-64; also Geol. of Canada, 1863, pp. 59-60, 506, 695, 737; also Min. Res., Ont., 1890, pp. 24, 67, 91 and 97.

(2) Trans. Amer. Inst. Min. Eng. 1903.

(3) Geol. of Can., 1863, pp. 506 and 737.

Lake Superior.' The first of these is a brittle massive ore associated with quartz and having a brilliant metallic lustre and a colour varying from tin-white to bronze-yellow. Its hardness is 5 and its specific gravity varies from 7·35 to 7·40. The mineral is variable in composition. The results of four analyses were as follows:

	I	II	III	IV
Arsenic..	37·36	44·67	.....	.....
Copper..	44·70	30·81	27·60	10·28
Nickel...	17·03	24·55	27·29	36·39
Silver....	.....	0·25	0·21	.....
Total..	99·09	100·28		

The above variable results are due to the material analyzed consisting of a mixture, in different proportions, of niccolite (nickel 44·1 per cent and arsenic 55·9 per cent) and domeykite (copper 71·7 per cent and arsenic 28·3 per cent).

The second ore, said to be from the same mine as the preceding, occurs as the gangue of native copper and native silver, which are scattered through it in grains. The material is amorphous, greenish-yellow or apple-green in colour, with a waxy lustre and a conchoidal fracture. It is very soft, polishing under the nail, and falling to pieces when immersed in water. It is decomposed by acids, and is found to be essentially a hydrated silicate of nickel. Under I is an analysis of one specimen dried at 212° F. Under II is an analysis of another specimen dried at a higher temperature. It contains, besides, traces of cobalt and copper, and appears to be identical with nickel-gymnite or genthite. Under III is a partial analysis of a specimen which contained small disseminated grains of the native metals.

	I	II	III
Silica..............	33·60	35·80	.....
Oxide of nickel........	30·40	32·20	20·85
Protoxide of iron......	2·25	.....	.....
Lime.............	4·09	.....	.....
Magnesia	3·55	.....	.....
Alumina..	8·40	.....	.....
Water..	17·10	12·20	.....
Cobalt..	.....	traces	.....
Silver..	.....	.....	2·55
Copper..	.....	traces	18·51
	99·39		

The arsenide of nickel (niccolite), has also bee nfound at the 3 A mine, on lot 3 A, of the township of McGregor, in the district of Thunder bay, Ont., where it occurs in somewhat large, nodular grains and bunches, together with native silver of a similar form, freely disseminated through a gangue of calc-spar, with some quartz. (1)

Nickel is seldom or never absent from the magnesian rocks of the Eastern townships, in the province of Quebec, and the various serpentines, steatites, diallages, actinolites, etc., always contain small quantities of this metal, rarely, however, more than two or three thousandths. It has never yet been found in any considerable quantities, although the chromic iron ore from Ham gave, on analysis, 0·22 per cent of oxide of nickel. (1) Dr. Harrington also found a small amount of nickel in the serpentine brought by Dr. Bell from Pigeon lake, on the Montreal river, Ontario. (2)

Mining for nickel was, at one time, carried on at lot 6, con. XII, of the township of Orford, in the province of Quebec, but operations had evidently been suspended for a considerable time before the year 1883 when Mr. Willimott visited the locality. (3) The presence of nickel at this locality had been known for a long time (4) but the deposit had not been opened up as a mine until long after its discovery. The location, known as the Orford Nickel mine, was developed by means of two small shafts, sunk on what appears to be a large calcite vein, enclosing small transparent green crystals of chrome garnet, and often penetrated by long filaments of pyroxene of a greenish or yellowish colour. The chrome garnet also forms large granular masses, holding sparingly disseminated, small, brass-like grains and crystals of millerite. The largest crystals, however, are generally found penetrating a beautiful cleavable variety of calcite, and often exceed three inches in length. The houses, mining buildings and smelting furnaces were abandoned in 1883, with the exception of one house, which was occupied by a caretaker.

A sample of iron pyrites, from the eleventh concession of the Seigniory of Daillebout, Joliette county, in the province of Quebec, yielded Dr. Hunt 0·55 per cent of oxide of nickel (=0·43 per cent of nickel) mixed with cobalt. (5)

A carefully picked sample of iron pyrites, occurring on lot 163 of the cadastral plan of St. Jerome, P.Q., was analyzed by Dr. Harrington and found to contain copper 0·05 per cent, cobalt 0·22 per cent and nickel 0·10 per cent. (6)

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(1) Ann. Rep. Geol. Surv., Can., Vol. V., 1890-91, Part R, p. 47.

(1) Rep. of Progress, Geol. Surv., Can., 1853-56, pp. 435-474; also Geol. of Can., 1863, pp. 507 and 614.

(2) Ann. Rep. Geol. Surv., Can., 1876-77, p. 483.

(3) Rep. of Progress Geol. Surv., Can., 1880-82, Part GG, p. 5.

(4) Geol. of Can., 1863, p. 738.

(5) Geol. of Can., 1863, p. 506.

Dr. Hunt mentions that a bronze coloured, impalpable variety of iron pyrites, in irregular, reniform or globular masses, which occurs with copper pyrites in the township of North Burgess, Ont., gave him on analysis 3·47 per cent of cobalt and 2·21 per cent of nickel. (7)

Dr. Adams analyzed a specimen of pyrrhotite, associated with a little chalcopyrite and sphalerite, with a small amount of intermingled chlorite, from Pic island, Lake Superior, and found it to contain 0·562 per cent of nickel and 0·138 per cent of cobalt. (1)

Dr. Hoffmann analyzed a specimen of iron pyrites from Londonderry, N.S., which he found to contain 0·144 per cent of nickel and 0·813 per cent of cobalt. (2)

Nickel has also been met with in British Columbia, at various localities, associated with pyrrhotite and other sulphides. Gersdorffite has been observed, in the form of small octahedral crystals, distributed through specimens which show an intimate association of massive pyrrhotite and chalcopyrite, from the Columbia-Kootenay property, one mile and a quarter northeast of the town of Rossland. The whole sample, which weighed 6 lbs. 10 ozs., was analyzed by Mr. F. G. Wait (3) who found it to contain 0·65 per cent nickel, with traces of cobalt.

Considerable interest has been manifested in the deposits of nickeliferous pyrrhotite occurring near St. Stephen, N.B. These deposits were first visited and described by H. P. H. Brumell (4). Dr. R. W. Ells, who visited the localities where these ore bodies occur during the summer of 1903, has furnished the following description(5):—

The nickel-bearing rocks of St. Stephen were specially examined, and found to consist of newer intrusives, instead of the Laurentian granites as at one time supposed. The rocks are chiefly of the gabbro type, which have penetrated and altered a series of black and grey slates, the edge of which has also been a matter of much doubt. They were at one time supposed to be of Silurian age, but from the absence of fossils this point has never been fully determined. As developed about the head of Oak bay it was supposed that here they might be the equivalents of some portion of the primordial of the St. John area, but this point also has never been determined by finding fossils. On the geological map of the district they are provisionally coloured Cambro-Silurian. They apparently underlie, conformably, the sandy slates which are regarded as Devonian, and which occupy the north-west portion of the county, and on this basis their age might be Upper Silurian.

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(6) Rep. of Progress Geol. Surv., Can., 1876-77, p. 482.

(7) Rep. of Progress Geol. Surv., Can., 1863-66, p. 217.

(1) Ann. Rep. Geol. Surv., Can., 1880-82, Part H, p. 15.

(2) Ann. Rep. Geol. Surv., Can., 1874-75 p. 14 and Vol. V., 1890-91, Part R, p. 48.

(3) Ann. Rep. Geol. Surv., Can., Vol. IX., 1896, Part R, p. 15, 16 and 38.

(4) Ann. Rep. Geol. Surv., Can. Vol. IV., 1890-91, Part SS, pp. 112-114; also Vol. X., 1897, Part M, pp. 27-30.

() Summ. Rep. Geol. Surv., Can., 1903, pp. 156-159.

They are extensively altered in many places, changing into mica and chiastolite schists, but these alterations are purely local, and caused by intrusions of the gabbro masses. They resemble, in certain points, pre-Cambrian schists, but not as a series. Further detailed examinations for fossils will be required to finally settle the question of their true horizon.

The nickel near St. Stephen occurs in pyrrhotite, as at Sudbury, but the associated rocks are of a very different geological horizon from those of the latter district. The pyrrhotite is found in gabbro masses, which cut a series of slates, and have altered these extensively along the contacts. The mineral occurs, apparently, in pockety masses, which are probably quite local in character. The ore is found at a number of points, but attempts at mining for nickel have been made chiefly at two places, on what are known as the Rogers and Hall farms. The former is usually styled the Todd mine, the latter the Carroll mine.

On the Rogers farm considerable work, mostly of an exploratory nature, has been done. A shaft, 12 x 12, has been sunk for twenty-four feet, and three trenches have been cut, with depths ranging from three to eight feet, the principal one being rather more than two chains in length, on a course of S. 54° W. magnetic. In this trench the ore is exposed for a little more than thirty feet along the line of excavation, the rest of the cut showing partly mixed ore and partly rock. The width of the ore body was not ascertained, as sufficient development work has not been done to decide this point.

On Hall's lot (Carroll mine) several shafts have been sunk, one of seventy-seven feet, one of fourteen feet and one of twelve feet. In addition, a bore-hole with a diamond drill was carried down from the bottom of the deepest shaft to a farther depth of 163 feet. From information obtained from Mr. J. Carroll the first forty feet of the main shaft was in ore, but from that point to the bottom the ore was mixed with rock.

The formations at this place are practically the same as on the Todd area. The openings are apparently near the eastern edge of the gabbro mass, since altered slates are seen in close proximity.

An examination of the specimens collected from one of these deposits, about three miles north of St. Stephen, was conducted by Mr. R. A. A. Johnston, ([1]) who gives the following description:—

'The material consisted of pyrrhotite, through which was disseminated a little copper pyrites, and a very small amount of quartzose gangue.' A partial analysis gives the results under I, or calculated on the material free from all gangue, under II.

	I.	II.
Nickel..	1·72%	1·82%
Cobalt..	0·16%	0·17%
Copper..	0·31%	0·33%

Pyrrhotite, in association with chalcopyrite, and a little magnetite, in a gangue of greenish-grey serpentine, obtained from Thompson's farm, St. Stephen, was partially analyzed by Dr. F. D. Adams ([1]). The pyrrhotite constituted approximately about one-fourth, by weight, of the whole. The pyrrhotite, carefully freed from the associated minerals, was found to contain, nickel 0·923 per cent, and cobalt 0·394 per cent.

Partial analyses by Mr. M. F. Connor, of this Department, were made of specimens, selected by Mr. R. A. A. Johnston, from both the Todd and the Carroll properties. The specimens from the Todd mine, consisting of nearly pure pyrrhotite, with a small proportion of intermixed chalcopyrite, and with about 10 per cent of gangue, gave nickel, 1·38 per cent, and cobalt, 0·21 per cent. The specimen from the Carroll mine, which was almost pure pyrrhotite, with very little chalcopyrite, and less than 5 per cent of gangue, gave nickel 1·35 per cent and cobalt 0·21 per cent.

It will thus be seen that the ore is of lower grade than that generally met with and mined at Sudbury, so that, for the present at any rate, unless large bodies are encountered, these deposits will not be able to compete with the much larger and richer deposits of Sudbury.

The rocks at all these places appear to be very familiar in character, and consist, for the most part, of a gabbro, varying from fine to somewhat coarse-grained. The presence of the pyrrhotite is indicated by masses of gossan at the surface, and in places the ore is largely mixed with rock. There does not appear to be any well defined contact of the ore body with the adjacent rock, and but little indication of a vein structure is visible. Outside of the ground covered by the trenches and pits the surface shows the gossan cap at a number of points, with a thickness ranging from a few inches to several feet. From the fact that this capping shows at several places east of the

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(1) Ann. Rep. Geol. Surv., Can., 1880-82, Part H, p. 16.

(1) Ann. Rep. Geol. Surv., Can., Vol. V. 1890-91, Part R, p. 39.

main trench on the Rogers farm, it is probable that masses of pyrrhotite will be found over a considerable area, but probably in many cases so mixed with rock that careful separation would be necessary after mining. The existence of these ore-bodies could be best proved by judicious boring with a diamond drill. The areas of gabbro are limited, and appear to rise in dome-shaped masses through the slate formation at a number of places. In the present state of development of the district but little information of a definite nature can be given as to future values.

At the location near Moore's mill, while the gabbro is seen at different points, the pyrrhotite appears to be disseminated in a mass of altered schistose slates. The ore here is, apparently, of a low grade, and the extent of the deposit not large.

Another locality where mining for nickel has been undertaken is on lots 11 and 12, range IX, of the township of Calumet (Calumet island), Pontiac county, in the province of Quebec (¹). The ore is mostly a pyrrhotite, containing both nickel and cobalt. The associated rocks are diorites, that cut a series of grey and rusty gneisses and crystalline limestones. A large knoll of the diorite rises to the south of the ore bed, which has a thickness of about twelve feet, and between it and the diorite mass is a band of crystalline limestone. The ore itself is associated with another band of diorite that apparently traverses grey gneiss, the latter being seen beneath, or to the north of the ore deposit. On the river a short distance to the south of this mine the formation is mostly a crystalline limestone, and the intrusions of diorite and granite in this rock can be readily seen. The band of pyrrhotite at the Cowen mine dips to the south at an angle of about 50°. A shaft has been sunk to a depth of about forty feet, and crosscuts have been made to test the width of the deposit.

A compact massive pyrrhotite, through which was disseminated small quantities of quartzose gangue, handed to Dr. G. C. Hoffmann by Mr. E. P. Cowen, was partially analyzed by Mr. F. G. Wait, giving the results under I. The gangue constituted 4·30 per cent, by weight, of the whole; so that, neglecting this, the pure sulphide would give the results under II.

	I.	II.
Nickel.	3·88%	4·06%
Cobalt.	0·32%	0·33%

A quartz-amphibolite, carrying a somewhat large quantity of pyrrhotite, some pyrite, a small quantity of chalcopyrite, and a very litttle zinc blende, was obtained from the southeast half of lot 6, range II, of

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(1) Ann. Rep. Geol. Surv., Can., Vol. XI., 1898, Part A, p. 119.

the township of Calumet. The pyrrhotite, freed from all gangue and associated minerals, was found by Mr. F. G. Wait to contain nickel, 1·48 per cent, with no cobalt. (¹).

Cobaltiferous löllingite (diarsenide of iron) occurs on lot 16, concession XIV, of the township of Galway. The specimen was received by Dr. Hoffmann from the late Mr. J. B. Campbell on July 21, 1888 (²).

The mineral, which was associated with a small quantity of pyrrhotite, and a little white translucent quartz, was massive and exhibited only in parts, and that but very indistinctly, any approach to crystalline structure. Colour, steel-grey; lustre, metallic; brittle; fracture uneven; streak, greyish-black; specific gravity, after correction for a little included quartz at 15·5° C., 7·028.

An analysis by Mr. R. A. A. Johnston, of carefully selected material, afforded the results under I. Deducting the gangue (silica), and re-calculating the remaining constituents to 100, we obtain the results under II.

	I.	II.
Arsenic	70·11	70·85
Sulphur	0·80	0·81
Iron	24·41	24·67
Cobalt	2·85	2·88
Nickel	0·78	0·79
Gangue (quartz)	1·69	....
Totals	100·64	100·00

This mineral had not previously been identified in Canada, and if found in quantity would be of economic importance.

The discovery of cobalt, nickel, arsenic and silver ores on the west side of Lake Timiskaming, Ontario, was made public in November, 1903. The deposits were discovered during the building of the Timiskaming and Northern Ontario railway, the roadbed of this new government railway running almost over the top of the first of the deposits discovered. The deposits lie five miles south of the village of Haileybury, which is 106 miles north of North Bay, and 333 miles north of Toronto. At the time of Prof. Miller's (³) visit, from whose description the present information is obtained, four veins of deposits had been located in the vicinity of a small body of water known as

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(1) Ann. Rep. Geol. Surv., Can., Vol. XI., 1898, Part R, p. 39.

(2) Ann. Rep. Geol. Surv., Can., Vol. VI., 1892-93, Part R, p. 19 and 43.

(3) Eng. and Min. Jour, Vol. LXXVI., Dec. 10, 1903, pp. 888-889, also Canadian Mining Review, Dec. 31st, 1903.

Long lake, lying about half a mile south of the southern boundary of lots 8 and 9, concession I of the township of Bucke. All of the veins cut through the slate and slate conglomerate of the Upper Huronian. The presence of dikes or sheets of the darker coloured eruptives was suspected, but they were not definitely recognized. The slate and slate conglomerate have a slight dip, and the veins referred to cut them almost vertically. The strike of the veins Nos. 1 and 3 is approximately northeast and southwest, that of 4 is east and west, that of 2 northwest and southeast.

Vein No. 1 lies east of the railway track, at the edge of a swamp, about a quarter of a mile north of the end of Long lake. It has been uncovered at three points which are within a few yards of one another. Medium-grained, dark-coloured conglomerate is found on one wall. At the widest opening the deposit has a width of over six feet, but the vein matter is more or less mixed with rock. The ore consists of niccolite or the arsenide of nickel, and smaltite, the diarsenide of cobalt, together with much native silver. On weathered surfaces the vein matter is coated with the beautiful decomposition product, erythrite (cobalt bloom). The green nickel stain (annabergite?) is also seen on some surfaces, but is usually masked by that of the cobalt. Nickel silicate (genthite) may also be present. The secondary mineral arsenolite (As_2O_3) also occurs. Native silver, in leaves, films and fine threads, and moss-like forms, is intimately associated with the nickel and cobalt minerals, especially with the niccolite, as well as in cracks in the rock and in the calcite veinstone. In weathered portions of the ores the silver shows distinctly. One sheet, composed chiefly of silver, had a thickness of nearly 0·375 of an inch and a diameter of about one foot. The silver appears to have crystallized earlier than the niccolite which has been deposited around it. The smaltite has formed still later than the niccolite.

On location No. 2, which lies about half a mile southwest of No. 1, the ore body is distinctly veinlike in form. The ore is a mixture of smaltite, and probably some closely related arsenide, such as safflorite ($Co\text{-}As_2$), and niccolite. It was found to have the following composition:—

	I.	II.	III.	IV.
Nickel	7·0	6·24	4·56	21·70
Cobalt	16·8	16·76	19·80	
Iron	6·3	....	6·20	8·89
Arsenic	69·0	66·60	60·30	63·55
Sulphur		3·57	4·09	5·38
Insoluble	0·9	....	2·40	0·60
Water	....	....	2·00	....

Analysis I was made by O. S. James; II and III are of average samples collected by W. G. Miller, the former from the uppermost opening, the latter from the middle or main opening, the analyst being A. G. Burrows. It was evident that III was somewhat weathered, as it showed considerable cobalt bloom. Analysis IV is by Dr. J. Waddell. It represents a specimen collected by Prof. Nicol. This specimen was not taken like II and III with the object of determining the average composition of the vein. Prof. Nicol states that a qualitative analysis showed the presence of small amounts of copper and lead, and the absence of antimony, bismuth and zinc.

This ore body, unlike the others examined, carries no silver in the parts so far discovered. Three openings have been made in the vein, over a length of 300 feet. The massive ore has a width of fourteen inches, but vugs in the wall rock, two feet or more from the vein, are filled with cobalt bloom. The walls, which are well defined, are of slate, and the vein is almost perpendicular, lying on the hillside about seventy feet above the level of Long lake, and a few hundred yards east.

Ore body No. 3 lies at the southern edge of Long lake, about half a mile southwest of No. 2. It is very similar to No. 1, consisting of native silver, smaltite, erythrite, and, in all probability, niccolite.

Vein No. 4 is about half a mile southeast of No. 3. The vein, averaging not more than eight inches, cuts a perpendicular bare cliff, facing the west, nearly seventy feet high. The vein is weathered away, leaving a crack in the face of the cliff in some places four or five feet in depth. Thin leaves of silver, up two inches in diameter, were lying on the ledges, and the decomposed matter was cemented together by the metal. It was found impossible to get a fresh sample of the ore with the hammer, the vein being so much decomposed. The weathered specimens, however, in addition to the native silver, contained erythrite, and the unaltered ore will be found in all probability to consist of smaltite and niccolite, in addition to the silver. Across a distance of eight inches a distinct banded structure was noticed, and there were twelve or fourteen layers of ore lying parallel to the walls. A sample of the much weathered ore from vein No. 4, which appeared to contain less silver than most of the samples collected, was found by Mr. A. G. Burrows to have the following percentage composition; Silver, 16·60; cobalt, 3·91; nickel, 1·42; arsenic, 16·79, and gold none. This ore is brownish to yellowish in colour, and has an earthy appearance. Its colour is due to the presence of several decomposition products, the oxides of iron, cobalt and nickel. A small amount of cobalt bloom is present. At the bottom of the cliff the vein cuts thin banded, dark grey or greenish, at times, almost black slate, which has a slight dip. The slate passes gradually, as far as could be discovered from the steep character of the cliff, into a coarse breccia-conglomerate in the upper part. The fragments in the conglomerate consist of quartz, slate, granite and other rocks.

On some of the native silver specimens there are small, black, speriodal masses, with little lustre. These appear to be the hydrated oxide of cobalt (heterogenite). Some of the deposits, on the silver, resemble asbolite. The carbonates of cobalt and nickel are also probably present.

Prof. Nicol, of the Kingston School of Mines, who afterwards examined the material collected, recognized the silver antimonide, dyscrasite, in association with the native silver of No. 1. He has also definitely determined the presence of chloanthite (arsenide of nickel). It is associated with the niccolite, and also occurs rather free from cobalt in some of the nodular masses.

Smaltite and erythrite have also been met with in small quantities associated with the basic igneous rocks, to the west of Rabbit lake, so that the whole area where such rocks occur in the Timiskaming and Timagami districts should be carefully prospected. Although the width and extent of these veins may not be very great, the character of the ore is such as to make them a distant economic possibility at the present ruling prices of the metals contained in them.

OTHER ASSAYS FOR NICKEL OF THE SULPHIDE ORES IN CANADA.

Since the discoveries of the highly nickeliferous pyrrhotite of the Sudbury mining district there has been very active prospecting for similar sulphide material. Numerous specimens from all parts of the Dominion have come to the laboratory of the Geological Survey Department for assay. The material thus submitted has been examined, and partial analyses have appeared from time to time in the reports of the Section of Chemistry and Mineralogy, which, besides appearing as separates, are included in the various annual volumes. It has been thought advisable to tabulate these results, arranging them according to provinces. All of the analyses have been conducted by Messrs. R. A. A. Johnston and F. G. Wait, assistants to Dr. G. C. Hoffmann, the chemist and mineralogist to the Geological Survey. These analyses are in addition to those which have been already quoted on previous pages of this bulletin.

PARTIAL ANALYSES OF NICKEL ORES IN CANADA.

ONTARIO.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
1	Clarendon, Frontenac co.	60·00	......	Trace.	0·20	....	R. A. A. Johnston.
2	Lot 10, con. IV., Creighton, Algoma.	16·00	......	None.	None.	.....	R. A. A. Johnston.
3	Schreiber, (2 miles west of) Thunder Bay dist.	None.	......	0·03	Trace.	...	R. A. A. Johnston.
4	Same locality	10·00	......	Trace.	Trace.	...	R. A. A. Johnston.
5	Darlington bay, L. of the Woods	20·00	......	"	"	...	R. A. A. Johnston.
6	E. ½ lot 18, con. III., Dalhousie, Lanark co	20·50	......	0·09	"	0·11	F. G. Wait.
7	Lot 15, con. A. Anglesea, Addington co.	37·89	Present.	0·10	"	0·16	F. G. Wait.
8	Lot 12, con. III., Galway, Peterborough co.	......	......	0·16	"	...	F. G. Wait.
9	Lot 18, con. IV., Galway, Peterborough co.	17·25	......	0·10	"	0·12	R. A. A. Johnston.
10	Lot 16, con. XIV., Galway, Peterborough co.	......	Present.	0·10	"	...	F. G. Wait.
11	S. end lot 16, con. XIV., Galway, Peterborough co.	......	"	0·05	"	...	R. A. A. Johnston.
12	Lot 16, con. XV., Galway, Peterborough co.	38·46	......	faint traces	....	....	R. A. A. Johnston.
13	Galway, Peterborough co.	......	......	0·04	Trace.	......	F. G. Wait.
14	Lot 1, con. XI, Somerville, Victoria co	62·36	......	fai. tr.	...	...	R. A. A. Johnston.
15	Somerville, Victoria co.	48·97	......	0·06	Trace.	0·12	F. G. Wait.
16	N. part of Victoria co.	......	......	0·15	"	..	F. G. Wait.
17	S. E. shore Vermilion lake, Nipissing dist.	......	......	0·05	Pres't.	...	F. G. Wait.
18	Lot 6, con. 1., Hyman, Algoma dist	......	......	...	None	1·55	R. A. A. Johnston.
19	English river, 9 miles N. of C. P. Ry., District of Rainy river	10·50	......	0·12	None.	0·13	F. G. Wait.
20	Near Jackfish station C. P. R., Thunder Bay dist	......	......	Trace.	...	...	F. G. Wait.
21	Twelve-mile lake, Minden, Haliburton co.	6·92	......	0·13	Trace.	0·14	F. G. Wait.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
22	Lots 32 and 33, con. XI., Sebastopol, Renfrew co.......	....	Present.	...	None.	0·10	F. G. Wait.
23	E. ½ lot 18, con. III., Dalhousie, Lanark co....	29·35	.. .. .	0·165	Trace.	0·23	F. G. Wait.
24	Matawatchan, Renfrew co......... ..	... . .	....	...	"	0·29	F. G. Wait.
25	Cutting on Whitney and Opeongo Ry., 7¼ miles from junction with C.A.Ry., Sproule, Nipissing district.	......	Present.	0·19	"	.....	F. G. Wait.
26	Lot 17, con. II, Westmeath, Renfrew co.	....	"	fai. tr.	None.	....	R. A. A. Johnston.
27	N ½ lot 4, con. IV., Graham, Algoma district.	1·04	....	0·49	Trace.	0·49	F. G. Wait.
28	S. ½ lot 8, con. IV., Dowling, Algoma district.	....	Present.	.... .	"	0·26	F. G. Wait.
29	W ½ lot 10, con. IV., Olden, Frontenac co.......	3·32	"	0·98	"	1·02	F. G. Wait.

EXPLANATIONS.

1. A greyish-white, gneissoid rock, through which was disseminated a somewhat large amount of pyrrhotite. The metallic portion of the ore contained 0·5 per cent of cobalt. 2. Coarse, granular pyrrhotite, in association with zinc blende, through which was disseminated a somewhat small amount of a dark-grey, schistose rock and white quartz. 3. Pyrrhotite, from an extensive deposit. Examined for Mr. Thomas Marks. 4. A fair sample of the pyrrhotite, from the same locality. Collected by Dr. Selwyn. A fine, granular, massive pyrrhotite, through which was disseminated a little quartzose gangue. 5. Pyrrhotite, with a dark-grey gneissoid rock. Examined for Mr. Mather. 6. Pyrrhotite, with a little pyrite, in quartz mica-diorite. Examined for Mr. W. C. Caldwell. 7. A dark grey gneissoid rock, through which was disseminated a fairly large amount of pyrrhotite, and a trifling quantity of chalcopyrite. 8. A compact, massive pyrrhotite. Examined for Mr. E. D. Orde. 9. A massive pyrrhotite, in association with very small quantities of pyrite in quartz. Collected by Mr. F. D. Adams. 10. A compact, massive pyrrhotite, with a little pyrite, and trifling amounts of chalcopyrite and quartz. Examined for Mr. R. H. G. Chapman. 11. Massive pyrrhotite, with very small quantities of chalcopyrite, quartz and felspar. Collected by Dr. F. D. Adams. 12. Quartz, carrying some pyrrhotite, and a small quantity

of pyrite. 13. Lot and concession not communicated. Massive pyrrhotite, with a very trifling amount of calcite. 14. Quartz, a little feldspar, and a very little garnet, carrying a small quantity of pyrite and pyrrhotite. Collected by Dr. F. D. Adams. 15. Pyrrhotite, with quartz, and a little garnet. Number of lot and concession not communicated. 16. A compact, massive pyrrhotite. 17. From E. V. Wright's claim, north of Northeast arm of Lake Timagami. A very fine crystalline, massive pyrite, in a gangue of quartz-diorite. Collected by Mr. A. E. Barlow. 18. Pyrrhotite, with mica and but little visible quartz. Collected by Mr. W. McInnes. 20. A very fine, granular pyrite with small quantities of pyrrhotite. 21. Compact massive pyrrhotite, with a little pyrite, and a small quantity of quartz. 22. Compact, massive pyrrhotite, with small quantities of chalcopyrite and pyrite, in a gangue of calcite, pyroxene, some hornblende, feldspar and a little garnet. Examined for Mr. L. Meany. 23. Quartz, with a little hornblende, carrying large quantities of pyrite and pyrrhotite. Examined for Mr. T. B. Caldwell. 24. Compact, massive pyrrhotite, with a small quantity of quartz and hornblende-gneiss. 25. Compact. massive pyrrhotite, with a few particles of chalcopyrite, and a small quantity of gangue, mainly quartz and feldspar, with a very little garnet. Examined for Mr. A. H. N. Bruce. 26. Pyrrhotite, with a little chalcopyrite, apatite and hornblende. 27. Massive pyrite, associated with pyrrhotite, chalcopyrite and danaite (cobaltiferous arsenopyrite). 28. A massive pyrrhotite, with which was associated a little chalcopyrite and a somewhat large proportion of gangue (vitrophyre-tuff.) 29. Granular, massive pyrrhotite, with a very little chalcopyrite, with a little gangue of feldspar, quartz and hornblende. Examined for Mr. J. Bawden.

QUEBEC.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
30	Lake Mistassini.....	37·00	....	Dist. traces	Dist. traces	.....	R. A. A. Johnston.
31	Lot 24, R. 18, Potton, Brome co.........	Small amount.	....	Small amt.	......	.....	R. A. A. Johnston.
32	Lot 24, R. 7, Clarenden, Pontiac co....	None.	.. ....	1·50	Trace.	1·50	R. A. A. Johnston.
33	Lot 2, R. 8, Eardley, Ottawa co.........	......	....	0·13	None.	......	R. A. A. Johnston.
34	Lot 14, R. 6, Aylwin, Ottawa co.........	....	....	......	"	1·68	F. G. Wait.
35	Lot 14, R. 5, Masham, Ottawa co.........	....	Present.	A litt.	...	Co. Ni 0·28	F. G. Wait.
36	Lot 14, R. 5, Masham, Ottawa co.........	....	....	0·11	None.	......	F. G. Wait.
37	Same locality.. ...	....	....	0 10	"	......	F. G. Wait.

EXPLANATIONS.

30. Pyrrhotite, in gangue of hornblende schist. Collected by Mr. Walter McOuat (Survey) in 1872. 31. Pyrrhotite, chalcopyrite and pyrite, with small amount of gangue. One specimen contained a very small amount, and the other a trace of nickel. 32. Pyrrhotite, but the material does not, so far as is known, occur in quantity. 33. A massive pyrrhotite. Examined for Mr. W. A. Allan. 34. Pyrrhotite, almost pure, or with quartz, feldspar, mica, hornblende and calcite. 35. Massive pyrite, with a few particles of chalcopyrite, and a somewhat larger proportion of granite. 36. Massive pyrrhotite, with a very little quartz. 37. Taken from a different part of the deposit. Pyrrhotite, a little pyrite and a very small amount of gangue of black garnet and pyroxene, and a very little quartz. Nos. 36 and 37 were examined for Mr. W. L. Marler.

BRITISH COLUMBIA.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni in metallic portion.	Analyst.
38	Near head of Barclay sound, Vancouver I	......	......	Trans.	Trace.	....	R. A. A. Johnston.
39	Monashee mine, near head of Cherry creek..............	......	Present.	None.	Trifl'g Am't.	...	R. A. A. Johnston.
40	Illecillewaet dist.....	16·75	Present.	0·12	Trace.	0·14	F. G. Wait.
41	Creek flowing into Downie creek, 20 miles above fork with Columbia R., West Kootenay district.....	......	......	Faint traces	....	.....	R. A. A. Johnston.
42	Crawford bay, Kootenay lake	......	Present.	Trace.	......	......	F. G. Wait.
43	Same locality	10·70	Present.	0·048	None.	0·053	F. G. Wait.
44	A few miles N. of Savona station, C. P. R., Yale dist...	10·17	Present.	0·031	.....	0·034	F. G. Wait.
45	Between N. Thompson and Clearwater rivers..........	......	Present.	Trace.	....	.....	F. G. Wait.
46	Mission City claims, townships 17 and 18, Westminster dist	36·50	Present.	0·055	Trace.	0·09	F. G. Wait.
47	Jervis inlet.........	14·80	Present.	0·24	Trace.	0·28	F. G. Wait.
48	King Solomon mine, Kaslo Slocan mining camp, West Kootenay dist.. ...	0·36	....	0·15	Trace.	......	F. G. Wait.
49	E. side, Upper Arrow lake, about 12 miles from its head, W. Kootenay dist....	....	Present.	.....	None.	0·12	F. G. Wait.

BRITISH COLUMBIA.—*Cont.*

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
50	Monte Cristo claim, Trail creek, Columbia river	......	Present.	......	Strong trace.	0·13	F. G. Wait.
51	Iron Colt claim, Trail creek, Columbia river	14·50	Present.	0·20	Strong trace.	0·234	F. G. Wait.
52	Bunbury claim, near Lac le Bois, Interior Plateau region	17·83	....	0·065	Trace.	0·08	F. G. Wait.
53	Humphrey claim, Lac le Bois. Interior Plateau region	59·20	....	0·04	Trace.	0·10	F. G. Wait.
54	Quartz creek (Salmon R.), 20 miles south of Nelson	....	....	......	......	Trace.	F. G. Wait.
55	Kootenay-Columbia property, 1¼ miles N.E. of Rossland.	29·03	Present.	0·65	Trace.	0·92	F. G. Wait.
56	Queen Victoria claim, 8 miles W. of Nelson	37·15	Present.	0·43	Trace.	0·68	F. G. Wait.
57	Evening Star mine, E. slope Mt. Monte Cristo, 1 mile N. of Rossland.	62·73	Present.	0·25	0·59	Ni.0·67 Co.1·58	F. G. Wait.
58	Leviathan Group of claims, Campbell creek, E. side of Kootenay lake	61·84	Present.	0·06	None.	0·16	F. G. Wait.
59	R. & K. claim, 1 mile N. of Argenta, W. Kootenay dist.	....	Present.	0·05	"	.....	F. G. Wait.
60	Kennedy lake, W. coast, Vancouver island	7·50	"	0·15	Trace.	0·16	F. G. Wait.
61	Two Sisters and Crow claim, Deer creek, Clayoquot, Vancouver island	41·00	Present.	0·69	Trace.	1·70	F. G. Wait.
62	N.E. ¼ Section, Block I., W. side of Texada island	....	....	Faint trace.	......	.....	R. A. A. Johnston.
63	Near Kruquot, W. coast Vancouver island	....	Present.	Trace.	...	..	F. G. Wait.
64	Mt. W. of Ice river, 6 miles from forks with Beaverfoot R., East Kootenay district	0·20	....	0·12	None.	0·12	F. G. Wait.
65	N. bank of the Thompson, about 5 miles above Lytton, Yale district.	17·72	Present.	0·08	Trace.	0·097	F. G. Wait.
66	Shuswap lake	15·75	Present.	Trace.	None.	..	F. G. Wait.

EXPLANATIONS.

38. A massive pyrrhotite. Examined for Capt. J. Jaques. 39. An association of white translucent quartz and dark green diorite, carrying large quantities of pyrrhotite, and a little chalcopyrite. 40. Pyrrhotite, with a little chalcopyrite, and a small quantity of a dark green rock. 41. Quartzo-feldspathic rock, with a large amount of pyrrhotite. Examined for Mr. J. D. Boyd. 42. Pyrrhotite, with a very small amount of chalcopyrite, in quartz. 43. Pyrrhotite, with small quantities of chalcopyrite and graphite, quartz, feldspar and mica. These two last were examined for Cockle Bros. 44. Massive pyrrhotite, with a few specks of chalcopyrite, and a small quantity of quartz. Examined for Mr. J. Dickenson. 45. Pyrrhotite, with small quantities of chalcopyrite. 46. Fine, granular pyrrhotite, with small quantities of pyrite and chalcopyrite, and a somewhat large proportion of gangue. Examined for Mr. D. Elliott. 47. Pyrrhotite, with some chalcopyrite, and a little galena, with a small proportion of gangue, composed of quartz and fine-grained diorite. 48. Compact, massive pyrrhotite, through which was disseminated very small quantities of quartz. Examined for Mr. H. E. Porter. 49. Quartz, with a little chlorite and mica, carrying small quantities of a compact, massive pyrrhotite, a little pyrite and a few specks of chalcopyrite. Examined for Mr. R. Sanderson. 50. Pyrrhotite, with a little chalcopyrite, and small quantities of quartzose gangue. 51. Exceedingly fine-grained pyrrhotite, with a little chalcopyrite, and small quantities of a quartzose gangue. 52. A feldspathic rock, carrying small quantities of pyrrhotite. 53. Quartzo-feldspathic rock, carrying small quantities of pyrrhotite. 54. Pyrrhotite and pyrite, with small quantities of calcite and feldspar. 55. Pyrrhotite and chalcopyrite, with a little gersdorffite, in a somewhat calcareous gangue. 56. Pyrite and chalcopyrite, with some pyrrhotite, in a gangue of andradite, quartz, and a few scales of mica. 57. Arsenopyrite and chalcopyrite, in a gangue of hornblende and calcite. Danaite or cobaltiferous arsenopyrite, carrying 3·05 per cent cobalt, also occurs at this mine (Ann. Rep. Geol. Surv. Can., Vol. VIII, 1895, Part R, p. 13). 58. Quartz, with a little feldspar, hornblende and graphite, with a small quantity of pyrrhotite, and a very little chalcopyrite. Examined for Mr. F. W. Pettit. 59. Massive pyrrhotite, with a very little chalcopyrite, and a trifling amount of quartz and feldspar. Examined for Mr. J. Turner. 60. Massive pyrrhotite, with a few particles of chalcopyrite, and a small quantity of gangue, made up mainly of garnet and calcite, with a little quartz and hornblende. 61. Chalcopyrite, with some pyrrhotite, and a small quantity of quartz. Examined for Mr. F. Jacobsen.

62. Very fine, granular, massive pyrrhotite. Examined for Mr. Alfred Raper. 63. Granular, massive pyrrhotite, with a very little chalcopyrite. Examined for Mr. G. H. Franklin. 64. Compact, massive pyrrhotite, with a little quartz. Examined for Mr. James Walker. 65. Fine, granular, massive pyrrhotite, with some pyrite, and very little chalcopyrite, with a gangue mainly of hornblende and quartz. Examined for Mr. Geo. de Wolf. 66. Compact, massive pyrrhotite, with a little chalcopyrite, and a somewhat large quantity of quartz. Examined for Mr. J. T. Edwards.

NEW BRUNSWICK.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
67.	L'Etete, Charlotte co	....	present.	present.		......	R. A. A. Johnston.

EXPLANATION.

67. Pyrrhotite, like that from St. Stephen, with a little chalcopyrite in a gangue of diorite.

NOVA SCOTIA.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
68.	Barrachois harbour, Cape Breton co. ..	....	....	trace..	none .	trace..	R. A. A. Johnston.
69.	Lutche creek, Cape Breton co..	25·40	....	0·75	trace..	1·00	F. G. Wait.
70.	Boularderie Centre, Victoria co.	12·41	present.	0·07	trace..	0·08	F. G. Wait.

EXPLANATION.

68. Pyrrhotite. Examined for Mr. Alex. McLeod. 69. Pyrrhotite, with a somewhat large amount of siliceous gangue, from the land of Mrs. O'Hanley, on the rear of George river. Examined for Mr. Alex. McLeod. 70. Massive pyrrhotite, with a few particles of chalcopyrite, and a little hornblende and quartz. Examined for Mr, William Haggerty.

MISCELLANEOUS.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
71	Deer river, (tributary of Churchill R.)....	42·20	....	0·06	Trace.	0·10	F. G. Wait.
72	Island, off W. point of Kogaluk R., East coast, Hudson bay, Ungava district..	48·00	....	0·08	Present.	0·15	R. A. A. Johnston.

EXPLANATIONS.

71. Pyrrhotite in a gangue of quartz, feldspar, and a little mica and graphite. Collected by Mr. D. B. Dowling. 72. Massive pyrrhotite, with a large amount of quartz.

THE NICKEL DEPOSITS OF SCANDINAVIA.

The nickel deposits of Norway and Sweden are of especial interest to us, since they resemble in all essential particulars the larger and richer deposits of the Sudbury district. It would be impossible, within the scope of the present bulletin, to give a full, or even satisfactory, account of these occurrences, and the various phenomena attendant on their geological associations, and the reader is referred for such details to the elaborate and epoch-making work of Prof. J. H. L. Vogt, of Christiania, Norway (1).

All of the Scandinavian nickel deposits are intimately related to masses of gabbro or norite. In Norway there are about forty of these masses with which deposits of nickeliferous pyrrhotite are associated, these being the largest nickel deposits in Europe.

These masses, which are undoubtebtedly of igneous origin, are either composed of gabbro, which is essentially an admixture of plagioclase feldspar and augite, or of norite, a closely related rock, made up principally of plagioclase feldspar and hypersthene (rhombic pyroxene). These masses of gabbroic material occur in the Archæan hornblende schists and gneisses, generally intruded parallel to their foliation or lamination but often cutting across them. The norite of all these masses shows a remarkable tendency to differentiation, so that the same mass, in different parts of its extent, will vary greatly in the relative proportions of the constituent minerals. The principal types of such differentiates are often distinguished as gabbro, olivine gabbro, and pyrrhotite gabbro and norite, olivine norite and pyrrhotite norite, while the decomposed representative is distinguished as uralite-gabbro.

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(1) Vogt, J. H. L., 'Nikkel forekomster og Nikkelproduktion.' Geol. Soc., Norway, Christiania, 1892. 'Sulphidische Ausscheidungen von Nickelsulphiderzen,' Zeit. für Prak. Geol., 1893, also 1894, 1895, 1900 and 1901. 'Ueber die Bildung von Erzlagerstätten durch Differentiationprocesse in Eruptivmagmaten.' International Geol. Congress, Zurich 1894. 'The Formation of Eruptive Ore Deposits.' Min. Ind. Vol. IV., 1895. 'Problems in the Geology of Ore Deposits.' Trans. Am. Inst. Min. Eng., Richmond, 1901. 'Platingehalt in norwegischen Nickelerz.' Zeit. für Prak. Geol., Aug., 1902

The ore is chiefly pyrrhotite, containing, when pure, from 2·5 to 5 per cent of nickel and cobalt, but as much as 7 per cent is sometimes found. These metals are usually present in the proportion of one part of cobalt to from seven to twelve parts of nickel. Associated with the pyrrhotite (Fe_8S_9) are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and, in some places, ilmenite or titaniferous magnetite. Chalcopyrite is never present in large amount. The pyrite usually contains more cobalt than nickel. In the nickel ore, in a few places, the mineral pentlandite (eisennickelkies), is distinctly discernible, and, in a single case, the mineral cobaltite.

The pyrrhotite, chalcopyrite and pyrite, are regular constituents of the gabbro or norite, occurring in small quantities all through the various masses, but, like the other constituents of the rock, are found more abundantly in certain places, and a gradual transitition can often be observed from the normal gabbro to pyrrhotite gabbro, and to masses of pure pyrrhotite, with little or no rocky or silicate admixture. Occasionally, the ore occurs in masses sharply separated from the norite, as at the Ertelien mine. These segregations of ore are, in the great majority of cases, situated either directly at or near the edge of the igneous masses, and Vogt regards these concentrations as distinctly comparable to the basic borders or edges, so often observed about granites and other igneous rocks, in which the basic borders are sometimes marked by similar gradual passages, and, in some cases, by rather abrupt transitions.

Prof. Vogt draws attention to the fact that the average proportion of nickel to copper in the Norwegian ores is about 100 to 40 or 50 and that in the Varallo (Piedmont, Italy) occurrence about the same proportion holds good, while in Canada, where the associated igneous rocks are more acid in composition, there is sometimes relatively more copper, 100 parts nickel to 100 or 150 parts of copper being found in some of the deposits.

Ratio of Nickel to Copper in some of the most important of the Scandinavian mines.

Name of Mine.	Content of copper corresponding to 100 parts of nickel.	Percentages of nickel and cobalt in the pure pyrrhotite.
Grägalten mine	75-80	about 2·50
Klefva mine	55	" 2·75-3·00
Ertelien mine	45-50	" 3·00
Bamle district	35-40	" 3·50-4·00
Flaad mine	37	" 4·50
Senjen mine	35-40 (about)	" 3·50-4·00
Dyrhaug mine	30-35	" 3·80-4·20
Beiern mine	20-25 (about)	" 7·00

The Scandinavian ores also contain small quantities of silver, gold, and metals of the platinum group, including platinum, iridium and osmium. The amount of these metals is shown by the following analyses of the matte, from the Ringerike and Evje nickel smelters. (¹)

——	Ringerike %	Evje %
Nickel	51·16	41·50
Cobalt	1·98	0·97
Copper	16·41	23·60
Iron	10·87	(13)
Sulphur	19·58	(20)
	g. per t.	g. per t.
Silver	85	140
Gold	0·5	1 (about)
Platinum	2·6	3 (about)
Iridium	0·1 (about)	
Osmium		

The mineral associations of the precious metals are shown by the following table (²) of analyses of the ore from the Flaad mine at Evje.

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(1) Zeit. für Prak. Geol., Aug., 1902, p. 259.

(2) Zeit. für Prak. Geol., Aug., 1902, p. 258.

—	Ni & Co.	Cu.	Insoluble.	A .	Au.	Pt.
				g.	per.	t.
	%	%	%			
Pyrrhotite (mainly)...........	4·37	0·35	9·02	4	Trace.	......
	·50	0·60	16·00	Trace.	0	......
	2·90	0·21	20·63	6	......	......
	3·31	0·67	17·46	Trace.	0	......
Chalcopyrite and pyrrhotite...	2·60	8·00	18·90	44	Trace.	......
	1·70	13·33	14·40	48	"	Trace.
Chalcopyrite.........	......	......	....	37	......	......
				80	......	Trace.

Mining for nickel began in Sweden between 1838 and 1840, at Klefva, (Smaland), and in Norway between 1847-50 at Espedal and Ringerike. In 1838, Berzelius showed that the pyrrhotite from the Klevja mine, in Smaland, in southern Sweden, contained nickel. Before that time this mine had been worked for copper. When the fact was announced that the ore contained about 3 per cent nickel it was decided to erect a smelting plant for nickel, this being the oldest nickel smelting plant in Scandinavia. In the beginning of 1840 Th. Scheerer, the professor of metallurgy in the University of Christiania (who had been born in Saxony, and was manager of the Modums works), described the new mineral eisennickelkies (with 22 per cent of nickel), from Espedalen (Gausdal). Scheerer also announced that nearly all the Norwegian pyrrhotite and pyrite contained nickel and cobalt. The publication of these results was really the cause of the erection of the nickel plant at Espedalen, which was in operation, on a large scale, between 1840 and 1850, with a staff of 200 men. This smelter, however, was closed down about 1855. In 1837 Scheerer analyzed the pyrrhotite from Modums, and found it to contain 2·80 per cent of nickel. This pyrrhotite had been obtained from the Ertelien mine, which, later on, proved to be the chief mine supplying the Ringerike nickel smelter. About 1700, these works had been used for copper, and had, in the first half of the century, a small plant for the production of vitriol and red paint. Scheerer supplied information to his friend, A. Roscher, (who is described as being descended from a mining engineer), as to where he had found the pyrrhotite. This man had also been working in connexion with the paint plant at Modums and Snarums. All of these facts combined helped to bring about the establishment of the nickel industry in Scandinavia.

Between 1850 and 1860, and towards the latter end of this decade, the nickel mines in connexion with the Kragero nickel smelter were started by D. Forbes and the two brothers J. and T. Dahll. During the nickel boom about 1870 there were several nickel refineries located in Norway, while, at the same time, the plants of Sweden, Austria-Hungary, and Italy, supplied a large quantity of nickel, but Norway, during this period, was the largest producer of nickel in the world. After the discovery of the nickel in New Caledonia, and its advent on the market between 1876 and 1878, the price of nickel fell to such a degree that most of the European nickel smelters closed down, or decreased their production, and from 1877-80 up to 1888-89 New Caledonia produced from two-thirds to three-fourths of all the nickel in the market. Quite recently the production of nickel from New Caledonia, has, in turn, been exceeded by that of Canada.

From 1848 to 1892 about 330,000 metric tons of nickel ore were mined in Norway. The maximum yearly output was in 1876, when 42,500 tons were mined. From that time, until 1892, from 5,000 to 7,000 tons per annum were produced. The average nickel contents of the ore per annum have been as follows; 1851-1860, twenty tons; 1861-1872, forty-five tons; 1873-1876, 215 tons; 1876, 360 tons; 1877-1880, 100 tons; 1881-1885, 125 tons; 1886-1892, 105 tons.

Since 1892 the production of Norwegian nickel ore and nickel, has been as follows.

	Nickel Ore metric tons.	Value $	Metallic Nickel metric tons.	Value $
1893........	2,397	6,480	113	70,605
1894........	2,355	5,400	103	63,450
1895........	494	1,080	17	10,530
1896........	315	.....	16	8,100
1897........	nil	.....	nil	......
1898........	nil	.....	nil	......
1899........	220	810	5	2,700
1900........	1,888	12,690	13	9,720

In 1901 the *Mineral Industry* states that twenty-seven tons of nickel were produced from Norwegian ores, but this is included in the United States production from imported ores.

In some of the mines small bodies of rich ore have been found, as for example, at Beiern, where ore was encountered with an average of 7 per cent nickel (nickel-bearing pyrite and pyrrhotite); and in other places with an average of about 5·5 per cent. In the better mines first class smelting ore can often be sorted out, but the grade of the bulk of the ore is much lower. In 1870 miners were satisfied with a yield of 0·8 to 1·3 per cent of nickel from the smelting ore, the actual assays of which were from 0·9 to 1.5 per cent. In later years, when only the richer mines have been operated, and hand sorting has been practiced with more care, the yield has increased from 1·4 to 1·5 per cent, almost to 2·5 per cent, with an average of 2 per cent. In the mines the cost of producing one ton of ore, assaying about 2 per cent nickel, varies from $1.67 to $3.09, averaging $2.38 (1)

From 1861 to 1891 Sweden produced nearly 80,000 tons of ore. From 1866 to 1875 the nickel contained in the Swedish ores averaged from sixty-five to seventy tons per annum; 1876-80, fifty tons; 1881-85, twenty to forty tons. Since 1886, however, the nickel contained in these ores has only averaged from ten to fifteen tons per annum. The last year in which there was any production of Swedish nickel ore was in 1891, when 483 tons were mined. None of the Norwegian mines are at present in operation, although attempts are being made to revive the nickel industry in that country. The keen rivalry of Canada and New Caledonia will, however, prevent any extensive operations, at least for many years to come.

NICKEL IN EUROPE.

Nickel was first produced at Schneeburg, on the suggestion of Dr. Geitner, who erected a plant for the manufacture of the alloy known as 'new silver.' They used, as their raw material, the dumps from the cobalt works. These dumps were soon exhausted, and it became necessary to prospect for nickel ore. Early in the last century several small nickel deposits were discovered in Germany and Austria-Hungary, as for instance at Dillenburg, in Nassau, which was provided with a smelting plant in 1843, Dobschau, in Hungary, etc.

The nickel deposits of Varallo, in Piedmont, Italy, are very closely analogous to the Norwegian occurrences, but the ore bodies are much smaller in size. The mines, which are at Cevia and Sella Bassa, were worked and the ore smelted between the years 1860 and 1870, the smelter being operated by the same company as the Schneeburg works in Saxony. Badoureau gives the production as about fifty-four tons of metallic nickel a year. (1)

In Spain, in 1875, they mined 440 tons of ore, but the ore bodies were not operated after 1877 or 1878. The mines which were situated in the province of Malaga were on small deposits of nickel silicate (pimelite) with 3·96 per cent of nickel.

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(1) Zeit. für Prak. Geol., 1893, p. 143.

(1) Annales des Mines, 1877.

At Rewdinsk, in Russia, attempts have been made several times, to mine the deposits of the nickel-magnesia-silicates (rewdinskite) with 4·8 to 19·2 per cent of nickel oxide, but the deposit is small. In 1873, 47·4 tons of ore were mined, and in 1887, 4·9 tons of metallic nickel were produced in the first three months, from which they calculated the yearly production at 40·9 tons of nickel.

In Wales, in 1882, thirty-eight tons and in 1883, forty-nine tons of ore were mined, containing 1·4 per cent of cobalt and 0·7 per cent of nickel.

Nickel refining is quite an important industry in Great Britain, where a large amount of foreign nickel ore is refined at the various works. The most important of these nickel refineries are at Kirkintilloch (near Glasgow), in Scotland, and at Erdington (near Birmingham) in England. Both of these belong to 'Le Nickel,' of New Caledonia, and are principally using garnierite as ore. Vivian and Sons' old and well known copper and nickel refinery at Swansea, Wales, the Mond Nickel Co's. refineries at Clydach (near Swansea) and Smethwick (near Birmingham), as well as the Wiggin's refinery in Birmingham, are, for the most part, working with foreign nickel sulphide material.

In France, no nickel ore has been mined, but after the discovery of the New Caledonia ore several refineries were erected, the first one being at Septêmes, near Marseilles, where, from 1876 to 1882, experiments were conducted on a large scale for producing ferro-nickel. Christofle's well known works at St. Denis, near Paris, between 1870 and 1880 produced about 120 tons of metallic nickel yearly. Later on the 'Le Nickel' plant at Havre was erected. The copper plant at Eguilles (Vancluse, near Lyons) has several times conducted experiments in the refining of nickel and at the Paris exhibition of 1889 several samples were shown produced by bessemerizing according to the Manchés process, which contained from 91 to 95 per cent of pure nickel. (2)

Lately, however, the Martha and Benno mines in Silesia, Austria, have produced ore. In 1899, according to the *Mineral Industry*, only eighty tons of nickel ore were mined, but this rose to 3,896 tons in 1900, and during the half year ending June 30, 1902, when there were 1,036 labourers employed at the mines and works, the quantity of ore treated was 5,689 tons, which yielded 108 tons of nickel. The mines are situated at Kosemitz, Züsendorf and Gläsendorf, a short distance north of Frankenstein. They are described by Illner. (1) The ore, which contains from 0·5 to 3 per cent of nickel, fills fissures in serpentine. Occasionally, these veins carry from 4 to 18 per cent of nickel. Only the two mines already mentioned are operated, the Martha having two shaft furnaces, capable of treating fifty tons of ore daily. The composition of the ore ranges as follows: SiO_2 60-65·4 per cent; MgO 8·5-12 per cent; Fe_2O_3 and Al_2O_3 6-8 per cent; Ni 2·3-3·5 per cent, and loss on ignition 8 to 15 per cent. Before smelting the ore is first mixed with gypsum or with calcium sulphite and limestone, crushed to 12mm. size and pressed into bricks. The shaft furnace is 5m. high, and is charged with the bricks and coke in the proportion of 180 kg. of the former, to 50 kg. of the latter. A very fluid slag is produced, containing 0·3 per cent of nickel, which is used in making slag bricks. The matte composed of about 31·4 per cent of nickel, 49·7 per cent of iron and 14·5 per cent of sulphur, is crushed and subjected to an oxidizing roast, in a two-stage reverberatory furnace, which is 6·13m. wide, and has a capacity of 300 kg. in eight hours. There are four furnaces of this type at the works. The roasted matte, containing approximately 65 per cent of nickel, 15 per cent of iron and 20 per cent of sulphur is run into a bessemer converter with sufficient sand to slag the iron oxide and is blown for forty-five minutes, thus raising the tenor in nickel to 77·8 per cent. This fine matte is pulverized and treated to a dead roast in the reverberatory, which converts it into a greyish green nickel oxide, containing 77·6 per cent of nickel. This oxide is pulverized, moistened, cut into small cubes, dried and charged with charcoal into fire brick muffles, that are heated in a regenerative gas furnace. After three hours' treatment in this furnace the metal contains 99 per cent of nickel, and 0·3 per cent of iron. The sulphur dioxide from the roasting is caught in water and the solution neutralized with lime, the resulting calcium sulphide being used as a flux in the shaft furnace.

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(2) J. H. L. Vogt., 'Nikkelforekomster og Nikkelproduktion,' Nor. Geol. Soc., Christiania, 1892, pp. 38-40.

(1) Zeit. für das Berg-Hutten-und-Salinenwesen, No. IV., 1802, p. 816; also Mineral Industry, Vol. X., 1901, pp. 485-486, and Vol. XI., 1902, p. 486.

Nickel ore is known to occur in Greece, Switzerland and Sardinia, but in none of these countries are the deposits large enough to permit of them being mined at a profit.

NICKEL IN THE UNITED STATES.

The existence of nickel in the United States was probably first made known in 1818, when Seth Hunt opened up the cobalt deposit, near Chatham, Conn. This important announcement was made as the result of an analysis of a trial shipment of this ore to England.(1)

These mines were at first opened for their supposed silver contents as far back as 1661. They were not, however, very remunerative to their successive owners, who in turn tried to operate them. In 1762 they were again tried, and in 1770 several parties associated themselves together for the purpose of operating them for their cobalt contents. In 1787, a quantity of the cobalt was shipped to China. In 1853, a creditable exhibit was made by the Chatham Cobalt Mining Co. of the ore from their mines and its products.

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(1) Whitney. 'The Metallic Wealth of the United States,' 1854 p. 497; also Proc. Col. Sc. Soc., Vol. IV., 1891-93, p. 381.

Perhaps the best known nickel deposit in the United States is that situated at Lancaster Gap, in Pennsylvania, about three miles south of the main line of the Pennsylvania railroad, and a little over fifty miles west of Philadelphia.

According to authentic history the Gap mines had been worked for their copper prior to the year 1744, and tradition, in the neighbourhood, states that they were discovered about the year 1718. For eighty or ninety years they proved unremunerative to the four or five different companies who tried to operate them, but in 1849, after they had been lying idle for thirty or forty years, the Gap Mining Company was formed, to again open them up for copper. This company obtained considerable supplies of copper, about enough to pay for running expenses, selling their product to copper smelters in Boston and Baltimore. In all of these earlier operations the millerite and pyrrhotite were cast aside as useless, being regarded by the miners as ordinary 'mundic' or pyrite. In the beginning of 1852, however, Capt. Chas. Doble, who had come to the work, first as a miner, but who subsequently became superintendent, was convinced that the material on the dump was not ordinary sulphide of iron, but some other mineral. Analyses of specimens, sent to so-called experts in Boston and Baltimore, were unsatisfactory, so that, in the latter part of 1852, or the beginning of 1853, a sample was sent to Prof. F. A. Genth, who, after analysis, pronounced it to be a nickel ore, at the same time giving the percentage of pure nickel present. The mines, which had hitherto been known as the Gap Copper mines, changed to the 'Gap Nickel mines,' but the expenses of mining the ore, and especially the difficulties of the smelting operations, rendered the enterprise too costly, so that the whole of the works were closed down in 1860. (1)

In November, 1862, Joseph Wharton acquired possession of the 'Gap mine,' and the deposit became a nickel producer in May, 1863, the ore obtained being treated at the refinery built by Wharton at Camden, opposite Philadelphia. The development of the New Caledonia mines had, in 1882, reached such a stage that the world's consumption of metallic nickel, which had hitherto been about 800 tons per annum, was exceeded by several hundred tons. On account of this over-production prices immediately fell in the forced sales, and Wharton's Camden refinery was obliged to close down about the end of this year. The advent in large quantities into the market of the Sudbury nickel proved a further disturbing feature, resulting in the final closing of the 'Gap mine' in 1891.

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(1) 2nd Geol. Surv. Penn., 'The Geology of Lancaster co.,' CCC, 1880, pp. 163-176.

The dark, basic rock whith which the ore body at the Gap mine is associated forms a lenticular mass or stock, extending about 1,500 feet east and west and 500 feet north and south, and lying in the midst of mica schists of the Georgetown series of Fraser. The rock consists mostly of green secondary hornblende, and although the change is very thorough recognizable remains of orthorhombic pyroxene and of olivine were revealed after careful search through a number of microscopic slides. Reddish-brown biotite is present, and, in some instances, considerable plagioclase appears, with occasional accessory titanite. The ore consists of pyrrhotite and chalcopyrite in largest amount, but pyrite is not lacking. Crusts of secondary millerite are also encountered, and often this mineral furnished a not unimportant portion of the nickel contents. Although some ore has been found in bunches within the lens-shaped mass of rock, the productive ground lies near the walls. The ore body is nearly, if not quite vertical, and the depth reached by mining was 250 feet, while, at times, the workings were as much as thirty feet wide. As mined, the ore contains from 1·3 per cent of nickel, 0·25 to 0·75 per cent of copper, and 0·5 to 0·15 per cent of cobalt. The ore is believed by Prof. Kemp, (from whose description the foregoing information has been obtained) to be the direct result of igneous action, the ore bodies being concentrated as such by reason of magmatic differentiation, (2) in this respect resembling the Canadian, Norwegian and Italian occurrences.

The 'Gap mine' at one time produced one-sixth of the world's supply of nickel, although its total production is only given as 2,000 tons.

The nickel deposits associated with the peridotites of the southeastern Appalachians, have, from time to time, claimed public attention and several attempts have been made not only to ascertain their true economic value and extent, but also to develop them to the stage of producing mines. Probably the largest and best known of these occurrences is situated in the vicinity of the town of Webster, the capital of Jackson county, in western North Carolina. The deposits in question underlie a strip of land running approximately north and south a distance of about 7,000 feet, and east and west nearly 1,500 feet. The north end of the deposit immediately adjoins, to the east, the town of Webster. The nearest railway station is Dillsboro, on the Murphy branch or division of the Southern railway, this station being 48·9 miles southwest of Asheville. A wagon road connects Dillsboro and Webster, the distance being about 3·5 miles. The ore is very closely allied to the celebrated garnierite or noumeaite from New Caledonia. It is a hydrous silicate of magnesium and nickel, but very variable in composition, particularly as regards the mutual replacement of nickel and magnesium. It is, therefore, not a homogeneous compound. It is amorphous, filling certain cracks with encrusting, delicate, hemispherical, or stalactitic forms, usually soft and friable, falling to pieces in water, unctuous to the touch, and adhering slightly to the tongue. It varies, in colour, from pale yellowish-green to rather deep apple-green, and depth of colour usually accompanies an increase in the nickel contents.

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(2) Trans. Am. Inst. Min. Eng. Vol. XXIV., 1894, p. 622-631.

Analyses of genthite (nickel-gymnite), from Webster, N.C.

	I	II
	%	%
Silica	49·89	55·38
Nickel oxide	16·60	17·84
Magnesia	22·35	15·62
Water	12·36	10·77
Alumina	.....	.....
Fe_2O_3 Iron	.....	0·56
FeO Oxide	0·06	.....
Cobalt oxide	.....	.....
Total	101·26	100·17

Explanation.

1. Analyses of genthite, from Webster, N.C., by Dunnington (Ch. News, 25,270, 1872, and Dana, System of Mineralogy, 6th Ed., 1892, p. 676). II. Analysis by P. H. Walker, (Am. Chem. Jour., 10, 44, 1888, also Dana, System of Mineralogy, 6th Ed., 1892, p. 681).

Although, as shown, some of the ore contains from 16 to 18 per cent of nickel oxide, no very large amount of similarly rich material could be secured in mining, and most of the rich nickel seams are occupied by greenish nickel silicate, which will assay from 5 to 7 per cent of nickel oxide. Much of this secondary vein matter is mixed with comparatively barren, partially decomposed peridotite, so that it would be impossible to effect a separation, on an economic basis, and the bulk of the material which could be secured as ore would assay from 1·50 per cent to 3 per cent of nickel oxide. The ore assaying from 2 to 8 per cent of nickel contains, in addition, 0·02 to 0·10 per cent cobalt oxide. These nickel deposits are found in intimate association with a mass of peridotite, made up principally of two varieties, which are, doubtless, differentiates of the same magma, viz.: dunite, made up almost entirely of olivine and chromite, and websterite, composed essentially of bright green diopside, and pale brown bronzite. The mode of occurrence and origin of these deposits are precisely analogous to those occurring in New Caledonia, Oregon and elsewhere. The development work undertaken consists of a series of parallel trenches or ditches which are excavated in some cases simply to the solid rock beneath, and, in others, to a uniform depth, in no case exceeding thirty feet. These trenches are designed to give an idea of the relative abundance and disposition of the veins of silicate material. A shaft was sunk, but to what depth has not been learned, while considerable prospecting by diamond drill has also been undertaken.

Nickel has, for many years, been known to exist in considerable quantities in southern Oregon, and some of the deposits are regarded as of commercial importance. The mineral josephinite, a nickel-iron compound (Ni. 60·45; Fe. 23·22), has been described by W. H. Melville as occurring in the form of pebbles and smooth boulders in the placer gravels of a stream in Josephine county, Oregon, which are supposed to have been derived from some dike of ultra-basic rock, whose location has not yet been discovered. (1)

Nickeliferous pyrrhotite has also been noticed in both Jackson and Douglas counties, but the nickel silicates of Douglas county are the only ores which appear to be worthy of other than a passing notice.

The deposits occur near the small village of Riddles, in the southern part of Douglas county, a station on the Oregon and California railway, 226 miles from Portland, and 547 miles from San Francisco. The nickel mines are situated on Piney mountain, about three miles west of Riddles, and are connected with this village by an excellent wagon road of easy grades. This mountain, as its name implies, is thickly covered by forest, rising to a height of about 3,400 feet above sea level, occurring as an isolated ridge in a sea of other mountains. It is, approximately, 1½ miles long by 1 mile wide, thus embracing an area of 1½ square miles, in which nickel deposits might be expected to occur. The rock underlying this area is a peridotite or 'saxonite,' composed essentially of olivine and enstatite, with a small quantity of accessory chromite and magnetite. The olivine predominates, forming more than two-thirds of the mass of the rock. The ore is a silicate of nickel and magnesium, and, as usual, very variable in composition. The mode of occurrence and origin of ores of this class have already been discussed in detail, and the Oregon occurrence presents no unusual features which are worthy of special or extended reference. The following analyses of carefully selected material will illustrate the chemical composition of the pure nickel mineral, but the bulk of the ore which could be economically secured and utilized, would, of course, be much lower in nickel contents.

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(1) Amer. Jour. Sc., Vol. XLIII, 1892, pp. 509-515.

	I	II	III
Loss at 110° C..	8·87	6·63	7·00
Loss on ignition..	6·99	....	....
Al_2O_3 and Fe_2O_3..	1·18	1·38	1·33
SiO_2..	44·73	48·21	40·55
MgO..	10·56	19·90	21·70
NiO..	27·57	23·88	29·66
Total..	99·90	100·00	100·24

Explanation.—Analysis I is by F. W. Clarke, (Am. Jour. Sc., Vol. XXXV, pp. 468-487; Nos. II and III are by Dr. Hood, (Min. Res. U. S., 1883, p. 404.)

The first discovery of these deposits was in 1864, and, in the fall of 1881, Mr. W. Q. Brown secured control of what appeared to be the most valuable portion, transferring his interest to an incorporated company known as the 'Oregon Nickel Mines.' It is stated that about $30,000 was expended in development work. In 1891 some of the nickel bearing area was secured by a Chicago corporation, called the 'International Nickel Mining Company,' which is said to have expended about $60,000 on development work. Extensive preparations were made to mine and smelt this ore, but much of the smelting and other machinery purchased was never even set in position. The Anglo-American Nickel Company, incorporated in 1893, and the Oregon Nickel Mining Company, also own property in this neighbourhood. The amount of development work done in connexion with these deposits is hardly sufficient to test their commercial capabilities. Numerous open cuts, short tunnels and shallow shafts from twenty to forty feet deep have been made, but nowhere has a vertical depth of over fifty feet been reached. (1)

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(1) Dr. W. L. Austin. 'The Nickel Deposits near Riddles, Oregon.' Proc. Col. Sc. Soc., Vol. V., 1894-96, pp. 173-196.

The Gem mine, in Fremont county, Colorado, may be mentioned at some length in this connexion, as it is very similar, in mineralogical composition, to the Haileybury occurrences discovered last autumn in Northern Ontario. The vein at the Gem mine is in hornblende schist, and the ores were principally copper, but nickel soon made its appearance, and at a depth of 15 to 20 feet became quite prominent. From the surface down to a depth of seventy-five feet the vein has an average width of 3·5 to 4 feet. At this point it pinched out, and with the exception of a narrow streak of ore, which may be its continuation, and which contained the same cobalt and nickel minerals, no further ore was encountered lower down. The nickel-cobalt minerals of this mine are accompanied by native silver, some of the mineral specimens being occasionally so permeated by fine wire silver as to be broken with difficulty. In 1882 twelve tons of ore, containing 12 per cent of nickel and 2-2·5 per cent of cobalt, with considerable chalcocite, were shipped. Later, about half a ton of selected ore, containing 34 per cent of nickel and 3-4 per cent of cobalt, were sent to Swansea, England. The mine, however, was involved in litigation, and the ore body was seemingly too small for any extended mining operations. (²)

Since the closing down of the Lancaster Gap mine the entire United States production of nickel, from domestic ores, has been derived from Mine la Motte, Mo., the metal being secured as a by-product in the treatment of lead ores. In 1899 this production amounted to 22,500 pounds, but in 1901 it had decreased to 6,700 pounds, while in 1902 the twenty tons of matte, containing nickel and cobalt, which were refined at the works of the Mine la Motte Lead and Smelting Company, yielded 5,748 pounds of metallic nickel. (³)

NICKEL IN NEW CALEDONIA.

The nickel deposits of New Caledonia have, for many years, enjoyed an enviable reputation, not only for the large and continuous supply of ore they have produced, but also for the high grade they have been able to furnish for purposes of export. From about the years 1880 to 1888 these mines produced from two-thirds to three-fourths of all the nickel in the market. From the latter year, however, the mines of Canada have been gradually increasing their output, and, in spite of many adverse circumstances, it is believed that, at the present time, the amount of nickel secured from Canadian

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(2) Thomas Charlton, Proc. Col. Sc. Soc., Vol IV., 1891-93, pp. 420-421.

(3) Min. Res., U.S., 1902, pp 265-266.

sulphide ore is considerably in excess of that produced from the New Caledonia silicates.

The only nickel ore that occurs in New Caledonia is a hydrated silicate of nickel, in which more or less of the nickel oxide is replaced by magnesia, ferric oxide and alumina. The ore is associated with chalcedony, a magnesian silicate resembling meerschaum or sepiolite, limonite or bog iron ore and serpentine. In addition to these there are usually small quantities of chromite and asbolite. The mineral is entirely free from sulphur, arsenic or copper, and, although, in the first instance, the deposits were regarded as the gossan-like material produced by the sub-aerial decay of nickeliferous sulphides, the extensive workings already undertaken have failed to reveal any traces of such material even in the deepest workings.

The mineral garnierite or noumeaite, characteristic of these deposits, was discovered by M. Jules Garnier, in 1865, and was noticed by him in 1867, (1) and was described by Liversidge in 1874 (2). The mineral is closely related to the nickel-gymnite, described by Genth in 1851, and for which the name genthite was proposed by Dana, in 1867.

As the following analyses will show it is very variable in chemical composition. The material analyzed was selected with great care, and will give a good idea of the composition of the purest varieties of garnierite as well as its intimate connexion with sepiolite, or silicate of magnesia, with which it is associated, and into which it passes by insensible gradations.

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(1) Bull. Soc. Geol. de France, Vol. XXIV., p. 438, Paris, 1867.

(2) Jour. Chem. Soc., Vol. XII., p. 613, July, 1874.

ANALYSES OF GARNIERITE FROM NEW CALEDONIA.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Silica	35·45	44·40	37·78	38·35	47·24	50·00	48·00	50·15	51·94	53·80	41·80
Nickel oxide	45·15	38·61	33·91	32·52	24·01	18·50	15·39	10·20	2·32	0·24	
Magnesia	2·47	3·45	10·66	10·61	21·66	15·80	16·92	17·43	21·35	24·82	37·38
Water	15·55	10·34	15·83	17·97	5·27	10·00	20·75	21·65	23·17	21·47	20·39
Alumina				0·40	1·67				1·36		
	0·50	1·68	1·57					0·57			1·26
Iron Oxide Fe_2O_3				1·15		3·50					
Iron Oxide FeO.		0·43									
Cao		1·07			Traces.	2·70					
	99·12	99·98	99·75	100·00	99·85	100·50	101·06	100·00	100·14	100·33	100·83

Explanation I. Analysis by Dann (Ber. Nied. Ges., Jan. 7, 1878). II. Analysis by Garnier (Comptes Rendus, 86,684, 1878). III. Analysis by Kiepenheuer (Ber. Nied. Gest., July 14, 1879). IV. Analysis of dark-green garnierite, from Nakety, by Liversidge (Minerals of New South Wales). V. and VI. Analyses by Garnier (Soc. des Ingrs. Civils, 1887). Analysis of a translucent, pale-green variety, from Oüaillon, by Liversidge. VIII. Analysis of similar mineral from same locality, by Liversidge. IX. A very pale-green variety from Bel Air mine, Kanala, by Liversidge. X. Another similar specimen from same locality. XI. Analysis by Garnier of white veins, in the green mineral (garnierite), resembling sepiolite.

At first, when mining operations were started, it was stipulated that the ore should contain from 12 to 15 per cent nickel, but now the minimum has been reduced to 7 per cent and it is stated to be difficult to secure more than 60,000 to 70,000 tons per annum of such a grade of ore, although, if the European smelters would lower their limit to 5·5 per cent, the production could be more than doubled. From 1875 to 1884, R. Flechner has calculated that 8·3 per cent of nickel was the average contained in the ore, while Du Peloux states that in 1884, 850 tons of metal were produced from 12,000 tons of ore, thus giving an average of 7·1 per cent. Croissille states that between 1880-85, 28,933 tons of ore were produced with an average of 10·5 per cent nickel. In the first years a large amount of ore, containing from 3 to 11 per cent nickel, was discarded as valueless for purposes of export, but lately these dumps have been overhauled and some of the material shipped. The largest New Caledonia company "Le Nickel," in its catalogue issued at Paris in 1889, stated that the various grades of their ore contained 8, 10 and 12 per cent of nickel. From 1876 to the present time the ore has varied in composition, as shown under I; under II is given the composition of the ore which was being shipped to Europe in 1876; under III the average composition of New Caledonia smelting ore, (according to Levat); under IV is given the average composition of the nickel ore, as it was shipped in 1899, according to E. A. Wineberg (Min. Industry, Vol. VIII, 1900, p. 435).

——	I.	II.	III.	IV.
	%	%	%	%
Nickel oxide	9 to 17	18·00	7 to 8	10·00
Silica	41 to 46	38·00	45 to 50	42·00
Iron oxide	5 to 14	7·00	14 to 16	10·50
Alumina	1 to 7	....	3 to 5	2·50
Magnesia	6 to 9	15·00	10 to 12	22·00
Water	8 to 16	22·00	14·00	12·00
Lime	....	....	....	1·00

The nickel contents of the New Caledonia garnierite, lately smelted, have averaged about 7 per cent of nickel, but each succeeding year sees a poorer product handled and shipped.

The ore is intimately associated with a peridotite, and its various decomposition products grouped together under the name of serpentine. Fresh, undecomposed pieces of this rock, made up chiefly of olivine, are said to contain as high as 1 per cent of nickel. These serpentines, which cover the larger portion of the area of the island, rise into a series of hills, which are from 400 to 4,000 feet above the sea, the general elevation being about 2,000 feet. The deposits generally occur on the tops of these mountains, so that transportation of the ore, mining materials and supplies is very tedious and difficult, and in many cases expensive roads and aerial rope-ways had been constructed to deposits which, in some cases, came far from realizing expectations as to extent and richness. The ore-bodies occur as veritable 'stock-works,' cutting the decomposed peridotite in all directions. Invariably, where the nickel occurs, the surface is covered with a highly ferruginous soil, in which pisolitic iron ore is very abundant. Although this decomposed remnant of the peridotite contains a little nickel, most of the nickel has been leached out to be deposited in secondary veins of nickel silicate in locations at various depths below, favourable places for such concentrations being in the vicinity of faulting and jointing planes. The veins vary in size from a few inches to as much as thirty feet, but they are exceedingly irregular in this respect, at one time becoming gradually narrow, while, in other cases, large deposits end abruptly against barren rock. These veins or deposits are comparatively shallow. It is true that one fissure was followed down about 600 feet in depth, but generally the veins give out from 75 to 100 feet below the surface. Without reference to the surface mantle or covering, from which most, if not all, of the nickel has been removed by leaching, the richest deposits are those nearest the surface, while the higher parts of any deposit are richer than those lower down. The comparative shallowness of the deposits is, however, compensated by the large areas they cover, and some of the mines have yielded from 30,000 to 100,000 tons of ore, and are still in operation. The mining is carried on by means of open cut work, the ore being secured by means of a series of benches. The pick and shovel are usually sufficient to loosen and remove the ore, but occasional blasting is sometimes necessary. The ore, when properly mixed, is carried by means of aerial rope-ways to ground tram-lines, from which it is transported by lighters to the ships.

Various methods for the extraction of nickel from these ores have been attempted. Garnier, whose name has been associated with these deposits from the date of their discovery, tried to smelt the ore directly to a nickeliferous pig iron, which was afterwards to be refined in a reverberatory furnace to ferro-nickel. The first part of the process proved satisfactory, and the nickel-iron pig obtained from the richer lumps contained 65-68 per cent of nickel, 23-29·5 per cent of iron, 1·5-2·5 per cent of sulphur, 3·5-5·5 per cent of silica and carbon occurring as graphite, and from 1·5 to 2·5 per cent of other impurities, and amongst them, phosphorus. It was found impossible to economically handle or to refine this product, owing to the presence of sulphur, which has a strong affinity for nickel. Various wet methods were then employed, which followed, on a large scale, the different operations used in making chemical analyses. The ore was first dissolved in acid and the metals removed by the use of lime or bleaching powder, and finally a solution, containing nickel alone, was obtained. From such a condition it is easy to produce the nickel by fusing with charcoal the dried nickel salt.

Later on, however, they adopted a dry method, in the preliminary stages. In the first years they smelted it, with the addition of a special Norwegian pyrrhotite containing nickel and copper. In order to remove the excess of iron and copper they now melt the ore in low water-jacketed blast furnaces, with materials containing sulphur (calcium sulphide obtained in the manufacture of soda by the Le Blanc process), or with gypsum. The gypsum, which is made up of both lime and sulphur, is reduced, the sulphur uniting with the nickel by reason of its greater affinity for this metal, while a portion of it is taken up by part of the iron, the rest of it combining with the silica, magnesia and lime and the remainder of the iron to form a slag. This slag contains about 48 per cent of silica, 12-13 per cent of iron and not more than 0·40 to 0·45 per cent of nickel. The nickel-iron matte contains about 50-55 per cent of nickel, 25-30 per cent of iron and 16-18 per cent of sulphur. This matte, by reason of its greater specific gravity, sinks to the bottom, permitting the lighter slag to be drawn off. This matte is in turn roasted and a portion of the sulphur thus removed. It is re-smelted with sand, and the nickel will again combine with by far the larger share of the sulphur, leaving a comparatively small proportion for the iron, while the remainder of the iron combines with the silica or sand to form a slag. By a repetion of these, or similar methods, the iron is finally removed, leaving a compound made up essentially of nickel and sulphur, which is roasted with nitrate of soda to produce nickel oxide. This is then mixed with charcoal, and reduced, by the application of intense heat, to metallic nickel.

Attempts have been made, from time to time, to partially refine these ores in New Caledonia, and blast furnaces were erected and in operation both at Noumea and Thio, as well as at Newcastle in New South Wales, but the difficulties of procuring coke, suitable flux and labour have hindered their progress, and most of the ore at least is now exported for smelting and refining purposes. Most of this ore is refined in France, where "Le Nickel" company have extensive refineries at Havre, but a large proportion is also refined at Kirkintilloch (near Glasgow), in Scotland, Erdington (near Birmingham), in England, and at Iserlohn (Westphalia), in Prussia. The Engineering and Mining Journal of May 20, 1899, notes that a cargo of 3,000 tons of New Caledonia ore is being sampled for the Orford Copper Company, the ore averaging 7 per cent nickel. The merging of the Nickel Corporation, Limited, and the Société Minière Caledonienne, of New Caledonia, as part of the International Nickel Company, will result in the smelting, by this company, of a considerable amount of New Caledonia ore, at their refinery at Constable Hook, N.J.

Although these deposits were discovered in 1865, it was not until 1873 that active mining operations were undertaken. In 1880, the Société le Nickel acquired the celebrated mines at Thio, but did not commence mining until 1887.

The following figures represent the production of ore and nickel from the New Caledonia mines.

PRODUCTION OF ORE AND NICKEL FROM NEW CALEDONIA.

Year.	Ore mined.	Ore exported.	Nickel contents.	Nickel contents.
	Tons.	Tons.	Tons.	Tons.
1875	327	....	....	
1876	3,406	....	....	
1877	4,377	....	....	
1878	155	....	.....	
1879		....	....	
1880	2,528	....	210	
1881	4,070	....	388	
1882	9,025	.....	749	
1883	6,881	....	561	
1884	10,838	.....	904	
1885	5,228	....	850	
1886	920	....	150 ?	
1887	8,602	....	1,350 ?	

PRODUCTION OF ORE AND NICKEL FROM NEW CALEDONIA.—*Con.*

Year.	Ore mined.	Ore exported.	Nickel contents.	Nickel contents.
	Tons.	Tons.	Tons.	Tons.
1888	6,616	......	900 ?	
1889	19,741	......	1,381	
1890	22,690	......	1,633	
1891	35,000	......	2,449	
1892	......	......	1,244	
1893	69,614	45,614	2,493	
1894	61,243	40,089	2.422	
1895	29,623	38,976	2,548*	(2,548)
1896	6,417	37,467	2,972*	(2,707)
1897	26,464	57,439	2,858*	(2,858)
1898	53,200	74,614	3,608*	(4,205)
1899	103,908	103,908	3,845*	(4,205)
1900	......	100,319	4,676*	(4,526)
1901	......	132,814	6,202*	(5,210)
1902	......	......	......	(3,620)

* Nickel contents of ore refined in Europe, according to Mineral Industry. The figures in brackets are production of nickel from New Caledonia ores, in France, Germany and England (according to Metallgesellschaft and Metallurgische Gesellschaft, August, 1903, p. 23).

METHODS OF MINING AT SUDBURY.

The methods usually employed throughout the Sudbury district for obtaining the requisite supply of ore consist, partly, in the sinking of shafts and the opening up of the ore body by means of underground levels, drifts and stopes, the whole of such mining operations being carried on under a solid roof. For this work very little timbering is required, although, in some cases, serious accidents involving the loss of one or more human lives have resulted from neglecting to provide even the small amount of timbering necessary where occasional slips, faults or slickensides occur. As a rule, however, the walls and roof are very solid, and, at the present time, every reasonable precaution is taken to guard against such accidents by frequent, careful and systematic scaling, removing all loose or menacing portions of rock or ore. The larger part of the ore, however, is secured by a combination of this method and a system of open cast work. This, which, in reality is a species of deep quarrying, is a very cheap and effective method of obtaining large supplies of ore, and these considerations, no doubt, contributed to its adoption in the first place. On the other hand, these open pits being exposed to the weather, work is, at times, carried on only with extreme discomfort to the men, or is even seriously interrupted during periods of extreme cold or otherwise inclement weather. At the same time it is open to the serious objection that it is much more dangerous to the men, and in spite of the most careful inspection and frequent scaling large bodies of rock and ore are liable to be detached by the action of frost, gravity or other agencies. Lately, a disposition has gradually developed to abandon in large measure much of the open mining, and to remove the ore by means of levels and stopes at regular intervals beneath these pit floors, cross-cutting the ore-body frequently by a series of drifts. Finally, after breaking away overhead, and providing an arched roof, the whole is stoped away to the level below, and the ore hoisted from thence by means of shafts. Only such pillars and supports as are necessary will remain standing, and the intervening spaces will be filled by rock and ore too lean to be utilized, the whole being supplemented, when necessary, by material from the dumps.

The system of open cast work, which has hitherto found most favour in the district, consists, first, in the sinking of a shaft of the required dimensions at varying angles, this inclination being governed, mainly, by the general dip and direction of the ore body. This shaft secures the necessary accommodation for the skipway for hoisting the ore, while, at the same time, it provides a manway for ingress to or egress from the underground workings, by means of ladders, with landings at frequent intervals.

The largest pit in the district is at the Creighton mine, where on the first of June last (1904), ore was being hoisted from an open cut or quarry, measuring about 350 feet long, by 275 feet wide and 62 feet deep. The pit, known as No. 2 mine of the Canadian Copper Company, at the end of January, 1903, was opened up on a chimney of ore, which, below the 200 foot level, is growing larger. At the bottom of the open pit, which has reached the third level at 217 feet below the surface, the average diameter is 120 feet. The new vertical shaft had, at the same time, reached a depth of 390 feet, the fifth level being at 374 feet. At the Victoria mine the main shaft has been sunk to a depth of 557 feet, with various levels, drifts and stopes. The west open pit at this mine measures 70 by 125 feet at the surface, gradually tapering to 50 by 100 feet at the first level.

Each mine is provided with a rock house as soon as its permanency is established, and a double skiproad leading to it from the mine. The steel skips, having a capacity of one and a-half tons each, are hoisted to the top of the rock-house, dumping automatically on a large inclined 'grizzly' sizing-screen, which separates the fine from the coarse ore. Most of the ore is sledged to a proper size for the crusher in the mine, although, sometimes, this operation takes place on the floor of the rock-house. The coarse ore falls near the mouth of the 15 x 9 Blake crusher, set to about one and three-quarter inches, which has a capacity of about twenty tons per hour, (or 400 tons for the usual two shifts of ten hours each). Occasionally, as at the Creighton mine, there are two of these Blake crushers, but usually one is considered sufficient. The ore is then passed into the upper end of a slightly inclined revolving trommel screen, where it is sized into three classes for the succeeding operation of roasting. The fines pass through three-quarter inch mesh holes in the trommel screen, the medium or ragging through one and three-quarter inch holes, while the coarse is discharged at the lower end of the screen and is caught on an oscillating sorting table, also slightly inclined lengthwise. The jerking motion of this table provides such a rate of travel of the pieces of ore as enables a certain number of boys, stationed along the side, to pick out and cast aside a considerable proportion of barren rock or very lean ore, at the same time permitting the purer and higher grades to continue their journey to the ore bins. Each of these sizes falls into a separate series of bins, from which ore of the required class is automatically loaded, by means of inclined steel chutes, into standard gauge cars, and hauled by locomotives to the roasting yards. At the time the surveys for the Copper Cliff mines area were being carried on there were three roasting yards. The old one, which was graded by Dr. E. D. Peters, is situated immediately west of the old or East Smelter, and measures roughly 2,000 feet long and 125 feet wide. This still remains in use, and by the removal of the East Smelter buildings has been increased to 3,000 feet. For some years a small roast yard was utilized about midway between the original Copper Cliff mine and the Ontario Smelting Works. The site of this, which measured about 1,000 feet by 125 feet, is shown on the large scale maps, but it has now been abandoned, as its situation so close to the works and residences at times occasioned great discomfort to the workmen and inhabitants. The main roast yard, which is in use at present, and which is capable of much greater expansion, is located to the northeast of the West Smelter, towards the Manitoulin and North Shore railway. At the time the surveys were made, it was about 2,700 feet long by 150 feet wide, and it could be very readily extended to measure 4,000 feet. It will thus be seen that without any great effort roasting ground with a capacity of from

250,000 to 300,000 tons is already available. Many of the mines situated at Copper Cliff are, of course, handy to the roast yards, but most of the ore at present being utilized by the Canadian Copper Manitoulin and North Shore railway a distance of about seven and a half miles, to Clarabelle junction, about a mile has to be brought by a branch railway to Sudbury, a distance of about three and a-half miles and then down the 'Sault' branch of the Canadian Pacific railway to the southern roast yard at Copper Cliff, a further distance of about four miles. The ore from the Frood, or No. 3, mine has to be hauled first to the Stobie mine, by a spur about 1·25 miles long, and thence, by the same route, from the Stobie mine to Copper Cliff. Neither of these mines are, however, in operation, as an abundant supply of very high grade ore is more easily procurable at the Creighton mine. At the Victoria mines of the Mond Nickel Company an aerial tramway carries the ore from the mine to the roast yeard, and thence to the smelter.

METALLURGY.

In the production of nickel and copper from a sulphide ore the following operations have to be considered.

1. Treatment of the ores, for low grade copper-nickel matte.
2. Treatment of the copper-nickel matte, for concentrated copper-nickel matte.
3. Treatment of this matte, for copper-nickel alloys.
4. Treatment of the concentrated copper-nickel matte, for nickel matte.
5. Treatment of the nickel matte, for nickel oxide and metallic nickel.

The first two of these operations are carried out at the smelting works in the Sudbury district.

ROASTING.

The metallurgical treatment of this ore commences at the roast yard, whither it is conveyed from the mines, and being piled in convenient heaps, on previously laid cordwood, is exposed at high temperatures, without fusion, or at most incipient fusion, to the action of currents of air. The object of this roasting is to bring about the oxidation of the iron, and incidentally of the sulphur, as complete as is possible without involving an undue loss of metal in the slags of the following smelting, and second, the expulsion of arsenic, if any should happen to be present. With the possible exception of the Worthington mine, and some other deposits in that vicinity, none of the ore of the Sudbury district contains any appreciable amount of arsenic or antimony. If the oxidation be very imperfect the resulting matte will contain so much iron that its bringing forward will be unduly costly, while if the oxidation be too thorough an undue loss will occur on smelting the roasted ore. At Copper Cliff and at Victoria mines the Canadian Copper Company and Mond Nickel Company have spared neither trouble nor expense in the construction and equipment of their roast yards. The sites selected consisted of flats or swamps which have been further graded or filled up, any natural roughness or unevenness being cleared away and levelled, and the whole being given a gentle slope, with carefully made drains, serves to remove at once any rain or surface water. These precautions have to be taken to prevent loss of metal as soluble sulphates. It has been frequently stated that any great loss is thus fully guarded against, but, so far as known, no deliberate attempts have been made to determine what amount is thus actually carried off by rain and melting snow. After the heap has been fired a crust rapidly forms, which is believed to give further assistance against loss, but during heavy or long-continued wet and stormy weather it is believed an appreciable amount is thus removed. Whether the saving of this is a commercial possibility is well within the range of experiment. Hollows in the burnt-out heaps are filled with stalactites, an analysis of one of which gave Mr. Donald Locke the following composition:—Cu O, 8·42 per cent; Ni O, 10·21 per cent; Fe O, 7·18 per cent, and SO_3, 27·53 per cent. The water, too, of the marsh adjoining, has a decided bluish tinge, and an iron object immersed in it is immediately covered with a thin coating of copper.

Open air heap roasting, as practised at Sudbury, is, with favourable weather conditions, an old, simple, cheap and very effective method of treatment for the elimination of the undesired surplus of sulphur from low grade sulphide ores. Experiments and trials have been made to profitably save this sulphur, by present methods, but the sulphur contents, averaging from 16 to 30 per cent, and for the most part approaching, in this respect, the first-mentioned figure, with iron from 33 to a little over 50 per cent, are, apparently, too low to permit of their economic winning.

Titus Ulké (¹) states that, 'during 1902, was demonstrated the commercial impracticability of cheaply roasting Sudbury pyrrhotite nickel ores, which do not average over 25 per cent of sulphur, in Herreshoff furnaces, in order to utilize the sulphurous acid gas thus

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(1) Min. Industry, Vol. XI., 1903, p. 490.

obtained to make sulphite pulp or liquid acid. The use of the dead roasted residue, in the making of ferro-nickel, was also found to be commercially unsuccessful. It is recognized that, unless this roasting in the Herreshoff furnace can be done mainly without the aid of extraneous heat, the cost, compared with heap roasting, is prohibitive, and that, in any case, the average percentage of sulphurous acid in the gas produced is too low to be economical for use in the manufacture of calcium bisulphite for making sulphite pulp.' On the other hand, Mr. E. A. Sjostedt, (1) metallurgist to the Lake Superior Power Company, who initiated and carried on these trials, states that the process has been worked out in a satisfactory manner, the pyrrhotite being roasted without extraneous heat, and yielding sulphurous acid in quantities that more than repay the cost of converting the raw ore into briquettes.

The results of operations for two weeks in 1903 showed an average recovery of 86·4 per cent of sulphur, and a total working cost of $1.86 per ton of ore. Such are the conflicting statements of experts who have been concerned in the practical working out of the process, but the popular opinion seems general that failure has followed these elaborate trials, which had the advantage of being conducted on a commercial basis, by skilled men, with every modern appliance to ensure success. The fact that the Lake Superior Power Company, during their later operations in the Sudbury district, had practically adopted the general system of heap roasting and smelting, seems to lend support to the view expressed by Mr. Ulké.

The sulphurous fumes from the roast heaps have destroyed most of the vegetation from within an area of between one and two miles of Copper Cliff, and have a very injurious effect on vegetation, and especially young and tender trees and plants, as far as the town of Sudbury. In the immediate vicinity of Copper Cliff the destruction wrought to all growing plants and trees is very complete, and a more desolate scene can hardly be imagined than the fine white clay or silt of the flats, through which protrude at intervals rough rocky hills, with no trees, or even a blade of grass, to break the monotony. Of late years, vegetation has, so to speak, become accustomed to the sulphur, and gradually, and as a result, the area affected by the fumes is becoming more circumscribed. The maple seems to withstand the sulphur the best, and trees of this species may be found fairly green in the immediate proximity of the roast yards. To add to this scene of desolation the houses are of wood, rarely painted, while most of the area is covered with half-decayed logs, stumps and upturned roots, all of which have a peculiar brownish tinge, the result of the sulphur, which acts as an excellent preservative. On the other hand, all the barbed-wire fences, telegraph lines and other iron objects are rusted, and rapidly eaten away, requiring to be frequently replaced. The removal of one of these roast yards has had a most marked effect, and the beneficial results which were sure to follow are even now beginning to be apparent, for the two remaining are situated to the east and northeast of the town, and thus the prevailing winds, which are from the southwest, will tend to carry the fumes away. With the persistent influence and guidance of the president and general manager, Mr. A. P. Turner, trees are being planted, certain areas graded and made into lawns, roads opened up and culverts and bridges fixed, while the tortuous course of a small stream running through the town has been straightened and deepened. It is hoped that these efforts at beautifying the place will meet with the success they deserve, and already the town has taken on a new appearance, due to these improvements. The fumes, which are free from arsenic, seem to have no injurious effect on man or beast, except on occasions when particularly dense and accompanied by fog, when they produce a peculiar strangling or choking sensation, accompanied on rare occasions by bleeding at the nose. The residents are all seemingly healthy, and suffer from no unusual complaints, while some even assert that the sulphur is a positive cure for catarrh, consumption, and kindred diseases. People, however, at first, complain of a strangling sensation, but this gradually disappears, and those who have resided there for a time miss the sulphur when removed to another place, and have even an ill-defined though rarely expressed longing for this seemingly heavy and satisfying atmosphere.

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(1) Eng. and Min. Jour., April 25th, 1903.

At the Murray mine a huge shed with numerous large chimneys was erected for the purpose of roasting the ore during the winter, but it was not a success in any respect. No great thought or care has in the past marked the efforts of some of the companies in the selection of a site for the roast yard, and the ore has been placed in heaps, where the natural surface of the ground permitted, with scarcely any previous preparation, such as grading and draining. The mechanical loss, alone, from such carelessness, must have been far from negligible. The main supply of fuel that can be secured and is used for the heap roasting is dead or dry pine, often still standing as tall bare rampikes, the remains of extensive fires which swept over the area about thirty-five years ago. This, during the first years of the operations, could be secured very readily and cheaply, but the extensive and continuous roasting has used up all available sources of supply close at hand, and this wood has now to be brought considerable distances by rail, and is often mixed with ordinary cordwood. At the Victoria mines, however, there is an abundant supply of this dry pine for years to come, and it is brought in by teams and sleighs during the winter, from the area immediately adjoining. This dry pine is very efficient for this purpose as it is readily kindled and produces almost immediately a short though fierce heat which serves to ignite the pile thoroughly, and this, once started, continues burning on account of its sulphur contents.

The roast heaps are rectangular in shape, varying in size from forty by sixty feet, and seven feet high, to sixty feet by 120 feet and eighteen feet high, containing, in general, from 200 to over 3,000 tons of ore. The small heaps of 200 tons are of 'split matte,' of which mention will again be made. Ore heaps are not less than about 600 tons. Heaps of from 800 to 1,000 tons should burn out in from forty to fifty days, the larger heap taking, in general, from three to four months, while occasional heaps containing 4,000 tons, which are the largest yet attempted and which were by no means a brilliant success, have been known to burn from six to seven months. The ore is piled on a bed of split wood, about one cord being used to twenty tons of ore. This wood serves to start the oxidation of the sulphur, iron, nickel and copper; the sulphur to sulphurous acid, the iron to iron oxide, the nickel and copper chiefly to sulphates. The sulphur, which, in general, averages about 25 per cent, is reduced to about 6 or 8 per cent, while the iron is, in large part, oxidized to ferrous oxide, and the associated norite or gangue is rendered more or less porous or disintegrated by the swelling and oxidation of the ore. An analysis of roasted ore, in December, 1888, gave F. L. Sperry 5·40 per cent of copper, 2·43 per cent of nickel, 7·92 per cent of sulphur and 25 per cent of iron and the rest gangue, chiefly norite or diorite. L. P. Silver (1) states that an average sample of the roasted ore gave 3·25 per cent of copper, 2·16 per cent of nickel, 8·32 per cent of sulphur, 25·61 per cent of iron and the rest gangue.

Donald Locke says that the roasted ore in 1902, being used by the Canadian Copper Company, assayed about 1·5 per cent of copper, 2·5 per cent of nickel, 6 per cent of sulphur and 26 per cent of iron. At the Mond Nickel Company no assays of the roasted ore are made, as it is so variable in composition and difficult to obtain representative material, and one-tenth is added to the assays of the raw ore to enable the furnace manager to make up a charge for smelting.

When an abundance of ore fines is in stock, over and above the usual requirements for covering and finishing the heaps, the excess is generally used to cover the ground on which the roast heap is to be built, to a depth of about six inches. The material is thus 'caked' together in the roasting, and after having served for several roastings is broken up and used as coarse ore, as it has only enjoyed an incipient oxidation. These roast piles are built up as follows: the place selected may or may not be covered with the 'fines,' as already mentioned, as occasion demands. Sticks of cordwood, of nearly uniform size, should be placed side by side across both sides and ends of the rectangular area. The whole interior of this may be filled in with old stumps, roots, ties or cordwood, as material comes to hand, but in such a way as to form a level and solid bed on which the ore is to rest. Over this is placed small wood and chips to fill up all the larger interstices, care being taken to provide small canals, filled with kindlings, at intervals of eight to ten feet, leading from the outer air to the center of the heap. As first practised these canals connected with 'chimneys' along the centre, which were specially designed to rapidly and certainly kindle the whole heap. These chimneys were usually built of four sticks or old boards, so fixed together as to leave an opening, communicating below with the draught passages. Five or six such chimneys sufficed for each pile, and they were made to project two feet above the upper surface of the heap, so that no pieces of ore could fall into the flue opening. Such precautions, to ensure certain kindlings, are, however, not needed, and the canals are amply sufficient for this purpose; besides, it was found that they induced undue local heating in their immediate vicinity, thus tending to incipient fusing or matting of the ore, which is to be specially guarded against. The bed of cordwood varies from nine to eighteen inches in depth, according to the size of the pile. This bed of fuel being completed the coarse ore to the extent of about 65 per cent of the whole heap is transferred by wheelbarrows from the cars over a narrow and roughly constructed trestle platform running the whole length of the heap. This plan is sometimes adopted by the Mond Nickel Company, at the Victoria mines, although in some instances the tram cars are deflected by means of a spur or branch line of the aerial tramway running over the roast beds. The car is then lowered, and the ore dumped directly at any place desired. The medium sized ore or 'ragging,' about the size of nut coal, is then carefully spread over the coarse ore, and lastly, the whole heap is covered up with fines, until a height of from six to eighteen feet is reached, according to the size of the pile. The whole structure should then form a shapely rectangular pile, with sharp corners, and as steeply sloping sides as the ore will naturally lie on without rolling (about 45°).

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(1) Jour. Can. Min. Inst., Vol. V., 1902, p. 544.

The heap is now finished, and only those openings connecting with the canals around the base of the pile are left exposed. Kindlings or cotton waste, saturated with oil, are applied to these openings, and these are simultaneously ignited. These openings are themselves covered with 'fines' as soon as the cordwood is burning freely. In spite of this ample covering the whole of the fuel, as stated by Mr. James McArthur, (1) is burned out in about sixty hours after lighting up. 'A complete oxidizing roasting process then begins, and continues until the end, namely, until the sulphur contents are so far reduced and burned off that there is not sufficient left to promote further combustion. The remaining portion of the sulphur (6 to 8 per cent) is enclosed and sealed up in non-porous portions of ore or matte, the semi-fused covering of which would require to be rebroken in order to expose fresh faces under heat and thus liberate the remaining sulphur. This could only be done by turning over and reroasting the ore, after the first roast was finished, but it is not at all necessary as the remaining sulphur is essential in the smelting of the ore, in order to produce a clean slag.' About twelve hours after the firing the whole heap should be pouring forth dense pale yellow fumes of sulphurous acid. Great attention is paid to the pile for the first few days to prevent excessive local heating, which frequently causes partial fusion of the ore, this tending to prevent successful roasting. The heap is carefully and systematically watched day and night, and all holes or fissures, caused chiefly by settlement due to the burning out of the fuel, are at once covered with 'fines' of raw ore. After the first few days are over the pile may be left to itself until cold enough to remove to the storage bins or furnace. After the period of roasting is over, and the pile is cold enough to be handled, the outer covering of partially roasted ore is first removed. This is more abundant along the sides and base, and the precaution is sometimes taken to cover up these portions of the pile with old iron sheeting, which materially assists in preserving the heat, thus aiding the roasting. The longer the period of roasting the less the matting, and, of course, the larger the heap, the smaller quantity of the outside covering or margin is left only partially roasted. When this outer covering is removed to be re-roasted the remainder of the heap is conveyed in wheel-barrows a few yards, in one case, to a sunken railroad which runs alongside of the roast yards. At the Mond Nickel Company it is loaded into cars, which are hauled up an inclined tramway to an elevated series of strong bins at the roast yard, from whence it is loaded, as required, into the aerial tramcars, and thus conveyed to the smelter.

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(1) Ann. Report, Bur. of Mines, Ont., 1903, p. 300.

The ore, when roasted, is aggregated together in large clinker-like masses. They are loosened and broken up into suitable pieces for smelting, usually by pick and shovel, but often the assistance of explosives is needed to help in the removal. This roasted ore is loaded on large side-dumping cars, and hauled by locomotives to the stock bins at the furnaces. An experienced workman knows the difference in the quality of roasted ores at sight, and is able to mix them roughly, as they are loaded into the cars at the heaps, to be taken to the smelter and dumped into separate bins. Here it is sampled, and again mixed by the furnace men and made into smelting charges and fed into the furnaces.

SMELTING.

The copper nickel ores of the Sudbury district are, at present, (June, 1904,) being treated by only one corporation, the Canadian Copper Company, but during the progress of our work in 1901 and 1902 both the Mond Nickel Company and the Lake Superior Power Company were also conducting smelting operations. The Mond Company produced both the blast furnace or standard matte, and the bessemer or converter matte, while the last-mentioned corporation restricted their refining process to obtaining the lower grade or blast furnace matte. The smelter of the Lake Superior Power Company, situated at the Gertrude mines, was completed early in June, 1902, and for some time was treating from 100 to 160 tons of ore daily. The matte resulting from these operations steadily accumulated at the works until the suspension of all operations of this concern in 1903, and, during this period about 2,000 tons of the standard matte were produced. This matte is stated to have contained 29 per cent of nickel and copper combined, the proportion of the nickel to the copper being as 2 to 1. It was proposed to further refine this product at a converter plant being erected at Sault Ste. Marie, or to ship it elsewhere to be refined. In addition about twenty tons of ore daily, out of a total production of 200 tons, were picked out as free as possible from chalcopyrite, which quantity was laid aside to be shipped to Sault Ste. Marie for the manufacture of ferro-nickel.

From 1889 to 1893 the Murray mine conducted rather extensive smelting operations, making both standard and bessemer matte. The average of the lower grade product was 8·5 per cent of nickel and 4 per cent of copper, while Walker's analysis of the latter showed it to contain 48·82 per cent of nickel and cobalt and 25·92 per cent of copper. The Dominion Mineral Company, during the same period, produced only standard or blast furnace matte, containing from 18 to 20 per cent of copper and 24 to 26 per cent of nickel. About 1893, and later in 1896 and 1898, the Drury Nickel Company, and the same corporation reorganized under the name of the Trill Mining Company, smelted and sold about 420 tons of blast furnace matte. During the early '90's, the Canadian Copper Company produced a considerable amount of high grade matte by the bessemer process, but the refiners seeming to prefer the standard or blast furnace matte the manufacture of this product was abandoned, and the bessemer plant, consisting of a cupola, and three converters, located at the East Smelter, has been left idle for the greater part of the time since. In the fall of 1900 the plant of the Ontario Smelting Works was installed by the Orford Copper Company, an organization closely related to the Canadian Copper Company, both of which, in April, 1902, were included in the amalgamation of these and kindred corporations under the name of the International Nickel Company. These works were designed to further refine the low grade or blast furnace matte of the Canadian Copper Company.

Before the erection of the new smelter, which will be described and figured later, the Canadian Copper Company had smelting plants installed in two separate buildings, known respectively as the East and West Smelters. The processes at the two smelters were alike, and they differed only in the number of their blast furnaces. At the West Smelter there were eight, and at the East Smelter five blast furnaces, in addition to the bessemer plant. Lately the East Smelter has been dismantled, and in a short time it is stated to be the intention of the company to pull down the West Smelter also, and concentrate all refining operations under one roof. At the time of writing no smelting is carried on at Copper Cliff, but the company have leased the Mond Smelter at Victoria mines for a period of six months, this lease expiring about the 1st of August next, and all refining operations going on at present are carried on at this place.

The smelting or blast furnaces have the form of a flattened ellipse, are nine feet in height to the charging door, and measure nine feet by five feet at the top, and nine feet eight inches by four feet four inches at the tuyeres, of which there are twenty-five (2 inch), arranged in two rows. They are made of steel with a water space of two inches between the outer and inner plates, and have for a bottom a cast iron plate one and three-quarter inches thick protected by fire-brick, the whole supported by four strong cast iron legs. A light dome of plate steel, brick-lined at the top and sides, covers the furnace, and in one side of this dome, on a level with the ore bins, is the feed door. The furnace gases pass to the stacks, (one to each pair of furnaces), through brick chambers with trough-shaped sheet iron bottoms. Here the flue dust, having an opportunity to be precipitated, is taken periodically from these chambers and added to the blast furnace charges. The smelters are situated at or near the ground level, and ore, coke and flux are brought into the building on an elevated track, and dumped into the bins on the feed floor level. The well, forehearth or settling pot, is built of cast iron water-jackets in four sections, with a water space of six inches, and rests upon four wheels, for convenience of moving it whenever repairs are necessary; a second well standing ready to be put in its place. When the forehearth is in position a square opening on one side is fitted by fire-clay to a corresponding opening in the furnace, and the molten slag and matte flow into the forehearth when the furnace is in blast. The feeding of the furnace is continued at frequent and stated intervals, and as the molten mass gathers at the base of the furnace it flows through the discharge hole into the forehearth, where the heavier or metallic portion, (matte), sinks to the bottom, while the lighter slag rises to the surface, to flow out in a continuous stream from a water-cooled, phosphor-bronze slag spout to a McArthur granulating trough, where it comes in quiet contact with a stream of water that has already done duty in the water-jackets of the furnace, and flowing in the same direction as the stream of molten slag. This granulated slag is carried by the water, which gradually filters away into the dump or into the slag wells, out of which the slag is elevated by means of a bucket elevator into high waste heaps. From these immense dumps road makers, and especially the Canadian Pacific and Manitoulin and North Shore railways, help themselves, loading this slag on cars by means of steam shovels for use as ballast, for which it is excellently adapted. It is much heavier than ordinary ballast and does not retain water and, therefore, is not so liable to wash-outs, or to freeze in winter and heave up the tracks, as does the ordinary sandy or silt ballast often used in the district.

The matte is drawn off periodically, the tap-hole for this purpose being situated at a lower level, which is opened with a pointed iron rod and afterwards closed with a plug of fire-clay. This process is usually attended with a display of fireworks, but, as the men engaged at it become very expert, the stream of liquid matte is very quickly and effectively stopped. The matte is then allowed to remain in the cast iron pots or moulds into which it has been tapped, until cool, when it is dumped out, broken by means of sledge-hammers, weighed, loaded on cars, and shipped to the Ontario Smelting Works for further treatment.

The blast is furnished by No. 7 Connersville blowers, discharging sixty-seven cubic feet of air blast per revolution, and making from 90 to 130 revolutions per minute, each blower being driven by an engine of fifty H. P. The blast is delivered at the tuyeres at a pressure of about fourteen to sixteen ounces per square inch.

The roasted ore, with which the furnace is principally charged, is a mixture of oxides, sulphates and sulphides of nickel, copper and iron, together with a certain amount of the basic silicate of the gangue. The process of smelting is very economical, the ore furnishing in itself the exact ingredients for fluxing. By the smelting of the ore with a small quantity of quartz in the blast furnace, using from 15 to 17 per cent of Connellsville coke, the iron is chiefly reduced to ferrous oxide and forms a slag with the gangue and quartz.

Under I and II, are analyses of this slag by Mr. Donald Locke, late assayer of this Department. Under III, is an average analysis, published by Mr. John Herdt, (1) while under IV, is an analysis by Mr. J. W. Bain. (2)

——	I.	II.	III.	IV.
Silica	34·16	32·58	38·00	26·67
Ferrous oxide	41·24	44·37	43·00	50·82
Ferrous sulphide	......	......	......	3·52
Lime	8·23	6·62	4·50	3·38
Magnesia	3·44	2·77	2·00	2·95
Copper	0·25	0·13	0·40	0·20
Nickel	0·23	0·23	0·45	0·10
Alumina	9·03	10·41	10·00	12·88
Sulphur	0·91	......	......	......
Totals	97·49	97·11	100·85	100·52

The nickel and copper, and some of the iron, unite with the sulphur to form a matte. Under I and II, are analyses of this blast furnace or standard matte, the results obtained by Mr. Donald Locke, in November, 1902; under III, is an analysis by Mr. J. W. Bain, (1900); under IV, is the mean of two analyses of matte, which were made by Mr. F. L. Sperry on the 22nd February, and the 2nd of March, 1899. Under V, is the copper and nickel determination for this matte in February, 1891, while under VI, are determinations for these same metals by Mr. L. P. Silver (1902).

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(1) "Les Mines de Nickel du District de Sudbury (Ontario)." Rep. Cham. de Commerce, Montreal, 1892, p. 39.

(2) Ann. Rep. Bur. of Mines, Ont., 1900, p. 217.

—	I.	II.	III.	IV.	V.	VI
Copper	14·69	14·53	19·87	26·910	17·24	20·35
Nickel	28·17	26·34	16·75	14·140	21·44	16·48
Iron	31·89	34·15	43·90	31·235	....	....
Sulphur	24·96	24·93	18·72	26·950	....	....
Cobalt	....	....	0·63	0·235	....	....
Slag	....	....	0·05	0·935	....	....
Totals	99·71	99·85	99·92	100·405	38·68	36·83

Each furnace, of which there were thirteen installed, puts through about 130 tons every twenty-four hours, the total capacity being about 1,800 tons per day.

Mr. Donald Locke gives the following average for a day's work of a furnace. In a day of twelve hours, using twelve ounce blast pressure, there were smelted 264,000 pounds of roasted ore, assaying:—

Copper	1·43	per cent.
Nickel	2·56	"
Silica	26·00	"
Sulphur	5·57	"

To this was added 3,600 pounds of quartz, with 98 per cent of ailics, using 45,300 pounds coke (17 per cent). There were produced 26,318 pounds of matte, containing:—

Copper	11·90	per cent.
Nickel	22·10	"

and 207,425 pounds of slag, containing:—

Copper	0·27	per cent.
Nickel	0·40	"
Silica	32·00	"
Iron	40·00	"

An extraordinarily good run was as follows—With a sixteen ounce blast there were smelted in twenty-four hours:—

Ore	510,000	lbs.
Quartz	2,250	"
Using coke	87,200	"

There were produced:—

Matte	44,231	lbs.
Slag	439,233	"

The furnace gases pass to the stacks (one to each pair of furnaces), through brick chambers, with trough-shaped sheet iron bottoms. Here the flue dust, having an opportunity to be precipitated, is taken periodically from these chambers and added to the blast furnace charges. Four samples, assayed by Mr. Locke in 1902, resulted as follows:—

	I.	II.	III.	IV.
Copper..	1·45	1·49	1·55	1·39
Nickel....	3·28	3·84	3·79	3·62

An assay of a typical sample, by Mr. L. P. Silver, (¹) gave copper 4·25 per cent and nickel 3·37 per cent.

In the roasting of the ore a large proportion is badly roasted, or, owing to the heat in the pile being too intense, the ore melts to matte and is not roasted at all. This should be re-roasted, and is so, to a certain extent, but when large orders are on hand this unroasted and partly roasted ore is smelted in the blast furnace, and the resulting low grade matte is 'split,' that is, poured out on the ground in layers of about half an inch in thickness, and broken up. Two assays of this 'split' matte, collected in November, 1902, gave Mr. Locke the following results:—

Nickel..	2·30 per cent.	3·43 per cent.
Copper..	3·26 "	3·56 "
Iron..	63·08 "	61·18 "

This matte usually contains from 7 to 15 per cent of the metals, and a typical sample analyzed by Mr. L. P. Silver, (op. cit.), contained nickel 6.01 per cent and copper 7.45 per cent.

This 'split matte' is broken up and taken to the roast-yard where it is roasted in small heaps (about 200 tons). After the necessary oxidation, the roasting usually lasting about thirty days, it is remelted, being added to the blast furnace charge in place of some of the ore, the matte thus produced being thereby much richer in metallic contents.

Previous to the installation of the plant at the Ontario Smelting Works the Canadian Copper Company still further refined their own blast furnace or standard matte by the 'Bessemer Process.' In these earlier years, about 1893, this was done on rather an extensive scale, but during the later '90's, there was no very constant or large demand for this higher grade of matte, and this method of concentration was only practised as occasion demanded. The converter

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(1) Jour. Can. Min. Inst., Vol. V., 1902, p. 456.

used was of the Manchés type, with a capacity of one and a half tons with a new lining, and three tons with an old lining.

The process is very similar to that followed in bessemerizing iron. The Manchés converters are cylindrical shaped vessels, with convex ends measuring usually about eight feet in length, with a diameter of about four feet. They are made of boiler plate, and lined with a thick layer of clay mixed with quartz.

In the first years much of the quartz used, and especially at the Murray mine, was obtained from the Bruce mines, where great quantities of 'skimpings' exist, resulting from the jigging of the ore from that mine during its operation in past years. This material consists of the crushed quartzose gangue, cleaned of all but a small proportion of the sulphides of copper constituting the ore. It carries but a small proportion of feldspar. The silica now to be used is obtained from a large vein of massive quartz, situated on the high range of norite hills near the shores of Kelley lake, a little over a mile south of the large new smelter.

The converter rests, with its axis horizontal, on a carriage running on a track. It is provided, on its upper side, with a mouth or throat through which it can be charged. The dimensions are: length seven feet, three inches; diameter five feet, eight inches. The blast is driven through the charge from two parallel series of small tuyere holes, piercing the lining along either side, below and along the length of the vessel. Opposite each of these tuyere holes corresponding holes are pierced through the tubes which run along the outside of the converter to supply them with blast. These holes are closed with wooden plugs, removable to admit an iron bar, which, being poked through them successively during the process of blowing, keeps the tuyeres clear and the charge stirred.

A gearing enables the converter to be rotated on the car about its horizontal axis, and the throat having been thus lowered, a charge of low grade matte from the well or forehearth of the cupola is run into it by means of a trough. It is then rotated back until the mouth is again vertical, and run around underneath a large hood connected with a stack in another part of the smelter house where it is connected with the blower.

At first a pressure starting at five pounds of an air blast is blown through the mass of metal, when a violent agitation takes place, and on raising the pressure to seven pounds white fumes appear. As there are none of the usual flame reactions the point at which to stop the blast, after the iron has been removed, and before the nickel has also begun to slag in undue amount, requires special experience and judgment. The end of the operation is determined mainly by a perceptible decrease in the temperature of the mass, as shown by the flame, but also of the fragments splashed or blown out of the converter, as well as by the size and appearance of the particles, which gradually become larger and more frothy, at the last issuing in pieces about the size of a man's hand. The duration of the blowing operation depends on the size of the charge, and the displacement of the converter spaces for the siliceous lining is gradually appropriated by the iron in the charge. Each charge is, therefore, greater than the preceding one, until the sixth or seventh charge is blown, when the converter is laid to one side for relining. As a result of this, the continuance of the blast generally varies from twenty to eighty minutes, averaging about fifty minutes.

During the bessemerizing process the iron is almost entirely removed, the sulphur lowered to from 10 to 15 per cent, and the copper and nickel combined to from 80 to 85 per cent. The iron unites with the siliceous lining to form a very fluid slag, which is spilled off the top. The amount of nickel lost by oxidation is very trifling, cobalt is perfectly scorified, zinc, arsenic and antimony are completely driven off, while bismuth, silver, gold and platinum are entirely concentrated in this matte.

The following are analyses of this bessemer matte:—

—	I.	II.	III.	IV.	V.	VI.
Nickel Cobalt	39·96	40·93	31·35	41·18	39·64	48·82
Copper	43·36	45·71	48·86	44·87	42·75	25·92
Iron	0·30	0·40	0·81	0·94	1·03	2·94
Sulphur	13·76			11·62	14·05	22·50
Gold	0·1 to 0·2 oz.			0·3 oz.	0·75 oz.	·000075
Silver	7 oz.			5·1 oz.	5·30 oz.	·001775
Platinum	0·25 oz.				0·50	·000430
Iridium						·000056
Osmium						·000057
Rhodium						Trace.
Palladium	0·25 oz.					Trace.

Explanations.—Analysis I is by Titus Ulké and is styled 'a fair average analysis of the Canadian Copper Company's bessemer matte.' (Min. Industry, Vol. III, 1890, p. 460); II, and III, are by Roberts-Austen, (Min. Proc. Inst. Civ. Eng., Vol. CXXXV. p. 30); IV, is an analysis by J. W. Bain, (Ann Rep. Bur. of Mines, Ont., 1900, p. 218); V, is an analysis by L. P. Silver, (Jour. Can. Min. Inst., Vol. V, 1902, p. 534); VI, an analysis by Dr. T. L. Walker of the bessemer matte from the Murray mine, (Amer. Jour. Sc. Vol. I, 4th

Series, 1896, p. 112; also Ann. Rep. Bur. of Mines, Ont., 1903, pp. 283-284).

Under Norway, on a preceding page, analyses of similar concentrated matte, obtained from the Norwegian pyrrhotite, are also quoted. These show the presence also of gold, silver and platinum in appreciable quantities. Speaking roughly the silver is only from one-half to one-quarter of that present in the Sudbury matte, the gold about the same as that in the Murray mine matte, which is only about one-quarter of that present in the mattes from the Copper Cliff and the Victorian mines, while the metals of the platinum group occur in about half the amount of that present in the Murray mine, this matte itself only containing less than half that usually present in the mattes produced from the Copper Cliff and Victoria mines.

Prof. Vogt also gives the interesting information that the proportion of these metals present in the Norwegian ores and mattes is one part of gold to twenty of silver, one of platinum to thirty of silver, one of silver to 5,000 of nickel and one of platinum to 150,000 of nickel.

The following are analyses of the converter or bessemer slag. All converter slags are returned to the furnaces for re-smelting, as they are so high in nickel.

	I.	II.	III.
Ferrous Iron..	66·6	67·1	67·6
Silica..	28·5	27·9	27·5
Nickel..	1·9	1·6	1·4
Copper..	1·1	0·8	1·2
Sulphur..	0·5	0·4	0·5

I and II. are analyses by Edwards, (Eng. and Min. Jour., May 2nd, 1896); III. is an analysis by L. P. Silver, (Jour. Can. Min. Inst., Vol. V, 1902, p. 549).

From about the beginning of November, 1900, until the destruction of the plant early in the spring of 1904, the blast furnace matte produced by the Canadian Copper Company was further refined at the Ontario Smelting Works, built and operated by the Orford Copper Company at Copper Cliff. These companies were closely allied, and were consolidated in 1902 under the management of the International Nickel Company.

The standard matte is brought from the Canadian Copper Company's works on cars, and put through a Blake crusher. It passes from that directly into a Krupp ball mill, where it is reduced to a fine powder. From the ball mill it runs on a belt conveyer, which raises it to a storage bin, and from this storage bin it is conveyed still further, as required, on belt conveyers, to the feed hoppers of the roasting furnace.

The matte is roasted in two Brown, straight-line, automatic reverberatory calciners, each with a hearth area of 140 feet by ten feet. Later, these furnaces were enlarged to 200 feet, and a third one of similar dimensions was also built. One furnace has six sets of ploughs, and the other seven. The ploughs make one complete trip in six and a half minutes. The plough carriage, on passing the automatic feeder, causes a certain amount of the powdered matte to fall into the furnace. Each furnace puts through forty-five tons of matte in twenty-four hours, and reduces the sulphur from 25 to 30 per cent down to 5 to 8 per cent, using four and a half cords of wood per furnace per day.

The roasted matte is discharged from the furnaces into the trough of a screw conveyer, which takes it to the feeding floor of the blast furnace.

The furnaces are of brick, usually known as the 'Orford' furnace, cooled in the region of the tuyeres by water circulating in pipes embedded in the brickwork. The furnace measures fifty inches by 128 inches at the tuyeres, of which there are seven.

The blast is furnished by two No. 9 Sturtevant, centrifugal blowers. The furnaces are fed by hand, the charge consisting of roasted matte, fed in powder form, with quartz tailings and some roasted ore.

Owing to the large amount of fines in the charge, great quantities of fine dust are formed—forty tons a week being a small figure, and often as high as eighty tons a week being produced. This flue dust, assaying about 11 per cent of copper, and 18 per cent of nickel, is put through the furnace again.

The matte and slag flow from the furnace continuously into an Orford siphon-tap forehearth. This consists of a rectangular box about four feet long, two feet six inches wide and eighteen inches high, formed of cast iron plates strongly bolted together at the corners and lined with a six-inch brick wall. It is divided into two parts, in the ratio of about two to three, by a nine inch division wall, with a slot on the level of the floor of the forehearth through which the matte can flow from the larger compartment, the forehearth fills, the slag being lighter floats, and only the matte is able to find its way to the smaller compartment through the slot at the bottom of the division wall.

When the forehearth is full matte and slag are discharged in separate and continuous streams, the former being received in cast iron pots. This refined product is shipped to the Orford Copper Company, New York, for the separation of copper and nickel. Two samples of this high grade matte, assayed by Mr. Donald Locke, contained as follows:—

Nickel	41·58	40·37
Cobalt	0·71	0·78
Copper	24·99	24·95
Iron	9·82	9·64
Silver	.....	2·50 oz. per ton.
Gold	0·15 oz. per ton.	0·10 " "
Platinum	0·50 " "	0·44 " "

Two samples of the slag collected at the same time, analyzed by Mr. Donald Locke, gave the following results:—

Silica	31·03	26·62
Ferrous oxide	64·31	66·72
Lime	0·22	0·24
Magnesia	0·08	0·09
Nickel	2·57	2·68
Copper	0·56	0·77
Alumina	0·54	0·54
Sulphur	0·49	0·30
Totals	99·80	97·96

This slag is taken to the Canadian Copper Company's works, and put through the blast furnace to recover the metal contents, which are too high to be neglected.

PYRITIC SMELTING.

Mr. James McArthur is authority for the following statement: (1) 'Cold blast pyritic smelting of sulphide ores has been carried on in Canada, off and on, and for long periods at a time, since 1879; not as an experiment but as a process. Thousands of tons of copper sulphide fines have been smelted with cold blast, and later on in recent years at Copper Cliff with cold and also with very moderately hot blast, (the latter about 400° F.), making in these recent operations some 18,000 to 20,000 tons of matte product. The coke consumption was about 5 per cent for both temperatures of the blast, the grade of matte product being almost identical. With a blast temperature sufficiently high—not less than 1200° F.—to counteract gumming at tuyeres, the sulphur contents of the ore, which should be the only fuel used apart from a small percentage of the iron, can be kept in ignition, and with a higher pressure of the blast we should get sufficiently rapid oxidation action, even in a large and fast smelting furnace, to produce a direct 30 per cent matte, or even seven into one from a raw 4 per cent ore as it comes from the mines, because if we can dispense with all carbonaceous fuel in first smelting and can use the sulphur contents of charge in its stead, we stop all reducing action, and in lieu thereof introduce a complete oxidizing action, oxidizing the iron and consuming the sulphur in the operation.'

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, pp. 302 and 303.

Just to what extent green ore will be employed, in place of roasted ore, under the new conditions which will obtain at the new smelter which is about to be described, and where the pressure will be forty instead of fourteen ounces, cannot be foretold, but it is expected that a very large amount of raw ore will be added to the furnace charge.

The drawings accompanying this bulletin are plan and sectional elevations of a 1000-ton smelter designed by the Engineering Company of New York (1). These were submitted to the Canadian Copper Company, who, after their approval and adoption, proceeded to instal this new smelting and power plant, in which are assembled the latest and best improvements and conveniences for every part of the work. It is confidently expected that this smelter will be in operation early in July (1904) (2).

In the erection of this smelter there were several objects that had to be borne in mind, among them the cheap handling of a large tonnage of ore, the storage during the winter months of materials such as coke and coal, which can be received by boat during summer; the elimination of all needless manual labour, and the thorough efficiency of the power department. The plant was designed to be erected on two levels; the large amount of slag produced had to be taken into consideration, and the disposition of this slag was an important factor in determining the site. The plant, as it now stands, was built along the face of a cliff on the northern side of the flat on which the town of Copper Cliff stands.

On the upper edge of the cliff a system of bins has been constructed for storage purposes. The smelter building proper is situated parallel to these bins, with the power-house at the northeastern end. A trestle was built on the grade level of the bottom of the bins, which is also the grade level of the charging floor connecting the charging floor with the bins and also with the power-house, making a circular track, running on both sides of the furnaces, and passing the coal chute in front of the power-house. After roasting the ore is loaded into fifty-ton hopper bottom cars, and drawn up to the top of the bins by seventy-ton locomotives. The track leading to the trestle is on an easy grade all the way, and is also connected with the main line leading to the Canadian Pacific railway.

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(1) The blocks for the drawings reproduced in this report were kindly loaned by the *Engineering and Mining Journal* of New York.

(2) Eng. Min. Jour., Vol. LXXVI., Dec. 31st, pp. 1008-1009.

All ore, flux, coke, &c., is handled on these tracks, and dumped directly into the bins. Running on the circular track underneath the bins, and into the smelter building and past the power house, is an electric railroad, with side-dumping cars drawn by electric locomotives. The ore, coke, &c., is loaded into these cars, and weighed on the end of the trestle. The furnace charge is dumped direct into the furnaces, and the coal into the pockets next the power-house.

As shown by the sectional elevations the site consists of two levels, with a difference of thirty-five feet in elevation. The upper level is the same elevation as the feed floor, and is occupied by a double track pocket trestle, 35 x 35 x 600 feet.

On the lower level are located the power-house, 156 x 102 feet; the blast furnace building, 84 by 283 feet; the foundation for the trestle carrying the electric tramway, connecting the storage pockets with the feed-floor; the coal-bins of the boiler room; the dust-chamber, sixteen feet wide, eighteen feet high and 444 feet long; the stock, fifteen feet inside diameter, 210 feet high; together with the necessary slag-tracks, sunken tracks for loading metal for shipment, tracks to store-house, &c.

The power-house is equipped with two Nordberg Manufacturing Company's horizontal, cross-compound, condensing, blowing engines, with steam cylinders thirteen inches and twenty-four inches by forty-two inches, and air cylinders, fifty-seven inches and fifty-seven inches by forty-two inches. When operating under the usual working conditions these engines will deliver 20,000 cubic feet of free air per minute, against a pressure of forty ounces, for use in the blast furnaces. One Nordberg Manufacturing Company's horizontal cross-compound, condensing, blowing engine, with steam cylinders fifteen inches and thirty inches by forty-two inches, and air cylinders forty inches and forty inches by forty-two inches, will deliver 10,000 cubic feet of free air per minute, against a pressure of fifteen pounds, for use in the converters. Two thirteen inch and twenty-six inch by twenty inch horizontal, compound, condensing engines, built by the Robb Engineering Company, to each of which is directly connected one 200 kw. 600-volt, three phase alternating current generator, built by the Canadian General Electric Company, each generator having its own exciter of eleven kw. capacity belt driven from generator shaft. The electrical energy thus generated is used for hoisting in and pumping at the mines, operating the electric tramway for charging cars ,turning the converters, and operating the travelling crane in the furnace building. The station is also equipped with one twenty-five kw. motor-driven generator set, for furnishing direct current to the electric locomotives. A travelling crane is installed in the engine-room for handling all this apparatus. A gravity oiling and oil filteration system is installed on all engines.

In the boler-room the present installation of boilers consists of four 400-H. P., 150 pound pressure, horizontal water-tube boilers, built by the Aultman & Taylor Machinery Company, of Mansfield, Ohio, and space is provided for two more boilers of the same size. The boilers are equipped with Potter Super-heaters and Tread-Kill shaking grates. The ashes are removed from the boiler ash-pit by opening a grate in the bottom, which permets them to fall into a bucket resting on a small flat car, which runs on a track in the ash-tunnel under the boilers. The car is then run outside of the building and a hoist lifts the bucket and dumps the ashes into an ash-bin, from which it runs into cinder cars.

Coal is brought to the power plant by the electric locomotive train above referred to, and dumped into bins built in the trestle along the west side of the building. Then it runs through coal chutes to one-half ton coal cars in the boiler-room, from which cars it is shovelled into boiler furnaces.

The only available water for boiler use contains considerable sulphuric acid and scale-forming elements, and to eliminate these the water is subjected to a chemical treatment and precipitation in a water purifying system built by the Industrial Water Company of New York. In this way the acid is neutralized, and the scale-forming material is removed before the water enters the boilers. The condenser is of the elevated barometric shape, built by the Alberger Condenser Company, of New York.

The blast furnace building contains two sectional, rectangular, water-jacketted, Holthoff copper blast furnaces, three stands for Holthoff converters, one forty-ton electric crane, the necessary matte-settlers, clay mills, silica and clay storage bins, etc. Room is provided for expansion.

In operation, the ore, coke and flux for the blast furnaces, silica and clay for lining the converters, and coal for the boilers are delivered into the top of the trestle pockets by standard-gauge cars—Ingoldsby drop-bottom in the case of the ore—and drawn from the bottom of the pockets into trains of six two-ton. thirty-six inch gauge, side-dump Koppel cars. which are hauled to the blast furnace. silica and clay storage bins, or coal bins. by twenty-five H. P. Canadian General Electric Company electric locomotives.

The slag and matte runs from the blast furnace into sixteen inch settlers, the slag overflowing into thirty-ton Pollock cinder cars, which are hauled to the dump by the standard gauge locomotives. The matte is tapped into ten-ton cast-steel ladles and taken to the converter by a forty-ton Case Manufacturing Company's electric crane. The same crane removes the converter shells for re-lining, and takes care of the converter slag and white metal, pouring them into moulds for return into the pocket trestle, or for shipment to the refinery. The coal bins at the boilers, and the silica and clay bins at the clay mills, are kept full by six-car trainloads of material.

The flue dust is drawn from the dust chamber into a standard gauge bottom-dump gondola, especially fitted for the service, and this car is hauled to the top of the pocket trestle on the upper level, and the dust drawn into a pocket fitted for the purpose, whence it is drawn to a briquetting machine, pressed into briquettes and added to the charge.

The electric tramway consists of two parallel thirty-six inch gauge tracks, running under two lines of grates under the pocket trestle, then over suspension scales to opposite sides of the furnaces on the feed-floor level, passing over the top of the boiler room, coal bins and converter lining house, silica and clay bins. The two tracks have cross-over connexions, but, under normal working conditions, each track carries a train entirely independent of the other.

The blast furnaces are fifty by 204 inches at the tuyeres; fourteen feet nine inches from centre of tuyeres to the feed-floor, and have, on each side, four lower jackets, each fifty-one inches wide and eight feet six inches high, and two upper jackets eight feet six inches wide, and six feet high. Each lowerside-jacket carries four six-inch tuyeres. Both ends of the furnace are made alike, so that either end can be used for removing matte and slag. There is no brick work under the deck beams. The converters are eighty-four by 126 inches and are tilted by a train of gears and a worm, driven by the electric motor.

The water for the plant is supplied by a sixteen inch pipe, running from a dam situated about 5,000 feet from the plant itself. The water is run by gravity into the jackets, and when drawn out is pumped into a tank above the smelting tank, for fire purposes, or into the reservoir which is near the foot of the plant, and the hot water is also used in the boilers in order to economize at that point.

The Mond Nickel Company refine the ore from their own deposits at Victoria Mines, a station on the 'Sault branch' of the Canadian Pacific railway, twenty-two miles west of Sudbury. Their smelter, before the erection of the new one now about completed at Copper Cliff, was the most modern and best equipped in the district. It not only produces standard or blast furnace matte, but further bessemerizes this into a concentrated matte containing about 80 per cent of nickel and copper, these two metals being present in about equal amounts, 18 per cent of sulphur, about 0·75 per cent of iron, and 0·25 per cent of silica. This is sent to England to be treated there by the Mond process for copper and nickel. Difficulties in connexion with the operation of their refining at Clydach, Wales, have, for the time being, caused a suspension in their mining and metallurgical operations in the Sudbury district, while their smelter has been operated by the Canadian Copper Company under a six month's lease, which expires about August 1st next (1904). It is authoratively stated, however, that these difficulties have now been successfully overcome, and that their refinery, greatly enlarged and with all the necessary changes, is ready to go to work. It is confidently expected that immediately on the expiration of the Canadian Copper Company's lease the smelter will again resume operations, under the former management, on even a larger scale than before. The North Star mine, on the Manitoulin and North Shore railway, is, at present, being developed under option by this company, under the direction of Mr. C. V. Corless, and the ore secured is shipped to Victoria Mines for treatment.

The roasting of the ore is carried on as at the Canadian Copper Company's works. The roasted ore is brought to the smelter by means of an aerial tramway from the roast yards, which are about one mile distant.

The smelter is erected on a sloping hillside, and has three levels, those of the feed floor, the furnace floor and the converter floor. The roasted ore is brought into the smelter to a platform above the third level, where the tubs are received by a boy after having been automatically unhitched from the haulage rope. The boy runs the tubs to the bins, tips them and hitches them, again empty, to the outgoing rope. The ore bins are situated above and behind the feed floors, so that the roasted ore can easily be discharged through chutes into the dump cars on the feed floor.

Assays of the roasted ore are not made owing to the difficulty of selecting samples, and without careful sampling widely different results are sure to be obtained. For the purpose of deciding the proper proportions of ore to be included in the furnace charges one-tenth is added to the assays of the raw ore. The averages of the daily assays of raw ore for July and September, 1902, made by Mr. T. M. Paris, chemist to the Mond Nickel Company, are given under I and II respectively, while under III is given an average of several months' assays.

	I.	II.	III.
Nickel	2·67	3·21	3·05
Copper	2·81	2·41	3·05
Insoluble	17·20	13·90	17·01

The ore is smelted in rectangular, steel, water-jacketed furnaces, twelve-feet high, forty-two by 120 inches at the tuyeres, and increasing slightly towards the top. The two furnaces (only one runs at a time) have each sixteen tuyeres, eight on each side, a cast iron water-cooled tap jacket and Hixon slag spout. This consists of a coil of one inch piping, cast around with cast iron so as to form a channel some four feet long, through which the matter and slag flow continuously into the forehearth. The spout is fully described in Hixon's 'Lead and Copper Smelting,' pp. 28-30. One furnace puts through about 170 tons a day, made up (for example) as follows:—120 charges each containing:—

	A.	B.
Flue dust	200 lbs.	
Tailings	200 "	250 lbs.
Converter slag	500 "	500 "
North Star ore	300 "	250 "
Roasted ore	1,600 "	1,800 "
Coke	300 "	300 "

The tailings are practically pure quartz, with a small percentage of copper from the Bruce mines.

The North Star ore (obtained from the North Star mine) is not roasted, and the quantity used is varied according to the amount of sulphur in the roasted ore. The charges are dumped directly from the dump-cars into the furnace through the open top, alternate charges being fed to the sides by means of a simple device consisting of a wrought-iron pipe about eight inches in diameter through the length of the furnace opening, and let down about three feet into the furnace. On this the charge falls and is deflected towards the sides. The blast for each furnace is furnished by a No. 6 Green blower. The forehearth is of boiler iron, ten feet in diameter, with six inch lining of fire-clay and quartz. In this the matte and the slag have every opportunity for a complete separation, and, owing to its large size, the converter foreman can always be assured of having sufficient matte ready for him when he requires it. When the hearth fills the slag spout is at first kept stopped up, so that the bath rises right to the top of the hearth and a stiff slag crust forms, which is covered with a layer of non-conducting coke. This forms the hearth cover.

After the formation of the cover the slag spout is opened and the slag overflows and is granulated by falling into a powerful stream of water, and is carried to the slag dump by means of a large cast-iron pipe.

Under I is given the average of the blast furnace slag assays for September, 1902; II is the average for several months in the same year, by Mr. T. M. Paris, of the Mond Nickel Company, while, under III, IV and V are similar assays, by Mr. Donald Locke of this Department.

	I.	II.	III	IV.	V.
Nickel...	0·30	0·34	0·31	0·25	0·28
Copper...	0·36	0·35	0·33	0·28	0·29
Silica...	31·20	31·31	30·50	32·00	30·70

The matte is tapped periodically through the water-cooled taphole flowing through sheet-iron channels lined with clay into the converters, which are situated on the lowest level of the smelter. About twenty to twenty-five tons of matte are produced per day by one furnace.

Under I is given the average of the metal contents of this blast furnace or standard matte for September, 1902. Under II the average for several months, in the same year, by Mr. T. M. Paris, while III, IV and V are assays by Mr. Donald Locke of this Department.

	I.	II.	III.	IV.	V.
Nickel...	15·20	16·53	13·80	15·00	15·50
Copper..	13·14	16·22	12·10	11·80	12·00

In the converter department are six Leghorn converters, only one of which is in use at a time, the others being repaired, lined or dried. The lining consists of a mixture of quartz and clay, the quartz being crushed and then ground in a Chilian mill, where it is also mixed with the clay and moistened.

In lining a converter the bottom is first put in and tamped firm; a tapering iron tub is then placed in the converter, and round this the lining is firmly tamped. When the lining is completed to the top of the tub the tuyere holes are punched, the tub lifted out, and the top of the converter put on. This is then lined and the converter moved to where a blast pipe can be connected. A wood fire is lighted and the blast turned on. The fire is kept up until the converter is wanted. The converters are moved from place to place by means of a travelling electric crane, commanding the whole floor of the converter department.

The first charge of a newly lined converter is only about one ton, but as the lining is eaten away the size of the charge increases, the average charge being about two tons. A lining lasts from eleven to twelve hours, about six charges being blown in this time. A blast of ten pounds pressure is employed.

During the blowing of a charge the slag is twice poured off into slag pots by tipping the converter, the blast being turned off during the pouring. The finished matte is poured into a clay-lined bucket, which is carried by the electric crane, and the matte tapped from it into flat, cast-iron moulds.

The following is an analysis of a clean converter slag, by Mr. Donald Locke of this Department.

Silica..	33·40
Ferrous oxide..	46·50
Lime..	0·93
Magnesia..	0·08
Nickel..	0·55
Copper..	0·45
Alumina..	4·60
Sulphur..	1·17

The total amount of copper and nickel skimmed off, or poured from the matte during the converting, is, of course, much larger than this, as the last skimming contains much pasty, half-fused substance containing matte, and being higher in nickel than the clean slag. The average, therefore, of the converter slags would be considerably higher in nickel, averaging about 1·5 per cent of copper and from 1·5 to 2 per cent of nickel.

The bessemer or converter matte contains as follows, according to two analyses by Mr. Donald Locke of this Department:

Nickel..	41·88	41·23
Cobalt..	0·33	0·52
Copper..	37·37	37·83
Iron..	1·07	0·77
Gold..	1/15 of an oz. to a ton of 2,000 lbs.	
Silver..	4·87 oz. “ “	
Platinum..	0·40 oz. “ “	

The slag is broken as soon as it sets, loaded into small cars and raised to the feed floor, to be put through the blast furnace on an inclined elevator on the west side of the smelter.

The matte, when cold, is crushed in a Blake crusher, and packed in barrels to be sent to England for further treatment.

A railway track passes the lowest level of the smelter to take away finished products, etc., and a track enters the upper level to bring coke, raw ore, quartz, etc.

The engine house, situated to the west of the smelter, contains the Riedler blowing engine for the converter, the blowers for the blast furnaces, a pump to furnish the hydraulic power for turning the converters, two dynamos—one working by day and one by night—which supply light and power for the crane for the two crushers—one for matte, the other for the quartz for the converters—for the Chilian mill, and for the aerial tramway. Power is furnished by five horizontal tubular boilers.

REFINING OF NICKEL.

The subject of nickel has not, until quite recently, received from truly scientific men that proper share of attention and inquiry which the known, desirable, physical properties of the metal demanded, these giving ample promise of its wide industrial application. Several reasons might be assigned for this apparently unwarranted apathy in regard to such a hopeful field of inquiry, but, doubtless, the most important influence related directly to the apparently limited distribution and supply of ores containing this metal, and the great, and, for a long time, insuperable difficulties encountered in all attempts at refining the ores so as to obtain an absolutely pure and uniform product. From 1840 to 1860 the production of nickel was less than 200 tons annually, derived principally from the mines of Saxony and Hungary, with much smaller quantities from Sweden and Norway. Between the latter date and the year 1876 the greatest proportion of the world's supply of nickel was obtained from the mines of Norway and Sweden, with much smaller quantities from Saxony, Hungary and the United States. Careful examination of the occurrences of these nickel deposits in the countries mentioned indicated their probable exhaustion at no distant date, especially if called upon to maintain a large and steady output. The prospecting undertaken resulted in no new discoveries of a startling nature, and everything pointed to a comparatively limited supply and demand. This state of affairs continued until about the year 1882, when the ores from the New Caledonia mines began to flood the market. A period of over-production followed, with its accompanying losses and uncertainties. The discovery of the Sudbury ores, in 1883, proved a still further disturbing feature, although, at the same time, it prompted and stimulated that scientific inquiry which had been so long delayed, resulting in the discovery of several processes, some of which although far from realizing expectations in regard to simplicity, economy and ease of manipulation, have produced metallic nickel on a commercial basis which contains as high as 99·70 to 99·82 per cent of fine nickel, the impurities being chiefly very small quantities of carbon, iron and sulphur.

Another influence which has contributed in no small measure to retard the progress of nickel metallurgy, and, no doubt, prevented the wide industrial employment of nickel, is the secrecy which has always been maintained by most companies who have been or are engaged in the mining and smelting of nickel. The indifference and at times positive unwillingness to impart information which would be of value or profit to the general public has probably received no greater emphasis than in the case of nickel. Various excuses, more or less urgent or reasonable, are furnished by those in control to account for their action in this respect, but gradually this barrier of silence is being withdrawn, and, in the case of the Sudbury district, the managers of the two principal companies have lately shown a commendable desire to give all reasonable details in regard to the mining and smelting operations carried on in Canada.

This universal secrecy has, in the past, not only been maintained with regard to the exact location, extent and production of the individual mines themselves, but was especially extended to embrace the metallurgical treatment of the ores, even in the preliminary stages of roasting, matting and bessemerizing, while many of the small details, on which most of the success of the later refining methods depend, are still jealously repressed, or made known in such vague terms as to be practically valueless. All of our text books seem in sympathy with this lack of desire to impart information, and, in most of those reference to the subject of nickel, or accurate and detailed knowledge in regard to this metal, is conspicuous by its absence. The secrecy was, no doubt, in the first place, prompted by the desire of deterring others from engaging either in the mining or refining of nickel, and, if so, it has utterly failed in its purpose. It has permitted, and even greatly favoured, the spreading of the wildest and most exaggerated statements in regard to the enormous profits accruing to all engaged in this business.

The public, and especially those who are interested in mining, are being constantly apprised of the location of nickel deposits which not only surpass all others in point of magnitude but also in their peculiar adaptability for refining purposes. Further investigation, by competent individuals, (when such are available, or happily chosen), usually discloses some well known prospect or abandoned mine. On the other hand, men who are possessed of ample means, and are willing to devote a considerable portion to the promotion of some legitimate mining or smelting proposition, are often approached by so-called experts, with a supposed new and secret process, but which is already well known to a certain few, favoured individuals, who have already expended large sums only to find that it is not a commercial possibility. Very few people have the necessary knowledge or any means of verifying or refuting the statements of these interested individuals, and are thus often prompted to unusual and unwise expenditures, while, on the other hand, their ill success in these particulars prevents them from investing in some good, wholesome mining and metallurgical enterprise when occasion offers, which, if full details were available and offered, would not be the case. Fling wide the gates of knowledge; break down the barriers of silence; and it is confidently predicted that the resulting free and wide exchange of opinions and experience will be of incalculable benefit, not only to the smelters and refiners who are engaged in the nickel industry, but will prompt, encourage and direct the inquiring students and investigators of nickel, with profit to the whole of mankind.

Numerous processes for the refining of nickel have been suggested and published, and, in many cases, elaborate experiments have been conducted, with varying degrees of success, to determine definitely their economic practicability. These could not be adequately or even satisfactorily discussed or explained within the scope of the present report even if all the necessary details were available for publication, but it may be well to refer, in general terms, to a few of those which are either at present producing nickel on a commercial basis, or seem to give promise of doing so in the near future.

All of these methods are based on certain well known and long established principles, which have, in some instances, been worked out in more or less detail, and which are embraced under the general description of the so-called 'wet' and 'dry' processes. Certain minor changes and additions, chiefly in details, have made the latest refining of nickel much more readily and economically possible. Even with the present improvements, both are open to very serious and grave objections, as their adoption, in the first place, necessitates a very large and expensive plant, which is liable to frequent renewal and change, while the many complicated operations, which are still far from being fully understood and the reactions appreciated, must entail a loss which is far from negligible. At the same time, however, the final product has, of late years, been all that could be desired from a commercial point of view. The 'wet' process, especially, which imitates, although on a large scale, the operations carried on in the chemical laboratory for the analysis of nickel, needs a very large and expensive plant if any extensive output is contemplated.

This must occupy a considerable area of ground, while a very long time must necessarily elapse before the ore is sufficiently refined to permit of its being placed upon the market. In the case of the Gap mine it has been stated that a year sometimes passed from the time the ore was taken from the mine before the product was in marketable shape.

The present methods of treatment make use of some of the more valuable features of both the 'wet' and the 'dry' processes, calling in the assistance of electrolysis in the final stages, and thus obtaining the metal in very pure form. In the treatment of the concentrated nickel-copper matte for the nickel-copper alloys, usually referred to under the general name of German silver, this bessemerized matte is first crushed to powder and roasted in a reverberatory furnace to remove all the sulphur, and the oxides are reduced directly to the alloy, either by smelting with charcoal or by reducing gases.

In the treatment of the concentrated nickel-copper matte for nickel matte, nickel oxide and metallic nickel, the most important methods for the separation of the nickel and copper are the Orford or American process, the Mond process and some electrolytic processes.

Nearly the whole of the matte produced by the Canadian Copper Company is refined by the Orford Copper Company at their works at Constable Hook, N.J., opposite Brighton, Staten island, by what is known as the alkaline sulphide process. There is considerable dispute as to the origin of this process, some holding the discovery to be of recent date, while others contend that the principle upon which it is based has not long been known but has been in successful operation for many years. Mr. Robert M. Thompson, in an account of the discovery of this process, as far as the Orford Copper Company is concerned, says that it was the result of an accident following a long series of unsatisfactory experiments to discover some process which would successfully and economically treat certain mattes which had been sold to the United States Government by the Canadian Copper Company. In visiting the works one day he noticed some pots of matte which were cooling in front of the furnace, and which presented a somewhat unusual appearance. On calling attention to this fact, and failing to get satisfactory explanations from either the superintendent or foreman, he proceeded to investigate, the result being the discovery of the governing principle which effected the separation and caused the yellow 'bottoms' and black 'tops.' After a long series of experiments, on a large scale, the process at present in operation was gradually worked out. Mr. J. W. Bain, (1) in his

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(1) Ann. Rep. Bur. of Mines, Ont., p. 220.

'Sketch of the Nickel Industry,' draws attention to the fact that in certain descriptions accompanying applications for English patents, dating as far back as September 5th, 1839, undoubted reference is made to this principal. Moreover, in a letter published in the Engineering and Mining Journal, in August, 1893, an ex-employee of the Vivian Company, at Swansea, states that the method had been employed for a number of years at that company's works. At any rate the application of the alkaline sulphide process as a definite scheme for the separation of nickel and copper was in a fair way of being lost to metallurgy, or, at least, to be employed in a very restricted manner, if the Orford people had not, so to speak, re-discovered the principle upon which it is based. Great credit is also due to this company for the thorough manner in which they have worked out the details, and made it a distinct economic success.

In the Orford nickel process, the concentrated or bessemer matte is smelted in a small blast furnace, with salt cake or crude sodium sulphate, a chemical which can be obtained readily and cheaply. The sodium sulphate is reduced to sulphide, which forms, with the copper and iron sulphides, a very fluid matte, of lower specific gravity than the nickel sulphide. On cooling, 'tops' and 'bottoms' are easily separated; in the 'tops' being the bulk of the iron and copper as sulphides, together with sodium sulphide; while the 'bottoms' contain most of the nickel, with small quantities of iron and copper. On exposure to the weather the soda in the tops is gradually converted into the caustic condition. These tops are now mixed with fresh matte and re-smelted, whereby the caustic soda is converted into sulphide of soda at the expense of the nickel in the bottom, producing again a fluid mixture of iron, copper and sodium sulphides, while the nickel, in a semi-metallic state, sinks to the bottom once more. By properly balancing these operations a pure sulphide of nickel is at last obtained, which is simply calcined with a little sodium nitrate to the nickel oxide of commerce. The oxide is either mixed with flour, molasses, etc., and pressed into cubes, or with charcoal and reduced to metallic nickel in cube or powdered form. This product is not strictly a homogeneous metal, but a loose sponge of metallic particles, which retains all the impurities contained in the oxide, with the addition of from 0·5 to 2 per cent of carbon. To produce the solid metal the oxide is melted direct with charcoal and a small quantity of flux, and cast into ingots.

On the following page a diagrammatic scheme that accompanied a paper by Titus Ulké (1) is reproduced, which illustrates fully and briefly the various operations necessary in the Orford process.

The Mond or carbon-monoxide process (2) is based on the fact, that if finely divided nickel is exposed to a current of carbonic oxide, at a temperature below 150° C., a nickel carbonyl is formed, with the formula Ni $(Co)_4$, which is volatile at a temperature above 43° C., and which is decomposed at a temparature of 180° C. into metallic nickel and carbonic oxide. Iron forms a similar carbonyl, but no other metal has been found to do so. In the process there were many technical difficulties to overcome, and it was not until 1898 that it was brought to that stage of development that demonstrated its practical importance.

The bessemerized Victoria Mines matte is first dead roasted, and for this purpose any suitable furnace may be employed. After roasting the matte averages about 35 per cent of nickel, 43 per cent of copper and about 2 per cent of iron. It is then treated with dilute sulphuric acid for the extraction of part of the copper, (about 66 per cent), and not above 2 per cent of the nickel. This copper is sold as crystallized sulphate of copper. The residue, after drying from this operation, assays from 45 to 60 per cent of nickel, (averaging about 51 per cent), and 21 per cent of copper. The third operation has for its object the reduction of the nickel and, incidentally, the remaining copper, to the metallic state, without including the iron. For this purpose it is treated in a tower 7·5m. high, and containing fourteen hollow shelves, which are heated with water gas to not more than 300° C., and preferably 250°, when much iron is present. The ore is moved from shelf to shelf by means of rakes operated by a vertical axle. The lowest shelves are cooled. The reduced charge is transferred to another similar tower, where volatilization takes place, in which part of the nickel is taken away by carbon monoxide and forms the compound nickel carbonyl, but the temperature must not exceed 100° C. The remainder from this volatilizer is returned to the reducing tower, and the charge continues to circulate between the two towers for a period of between seven and fifteen days, until about 60 per cent of the nickel has been removed as nickel carbonyl. The nickel carbonyl passes to the decomposer, either a tower or a horizontal retort, which is heated to a temperature of 180° C., so as to decompose this compound, and release the nickel in a metallic state, preferably on granules of ordinary commercial metal. The carbon monoxide is also released, and is returned to the volatilizing tower,

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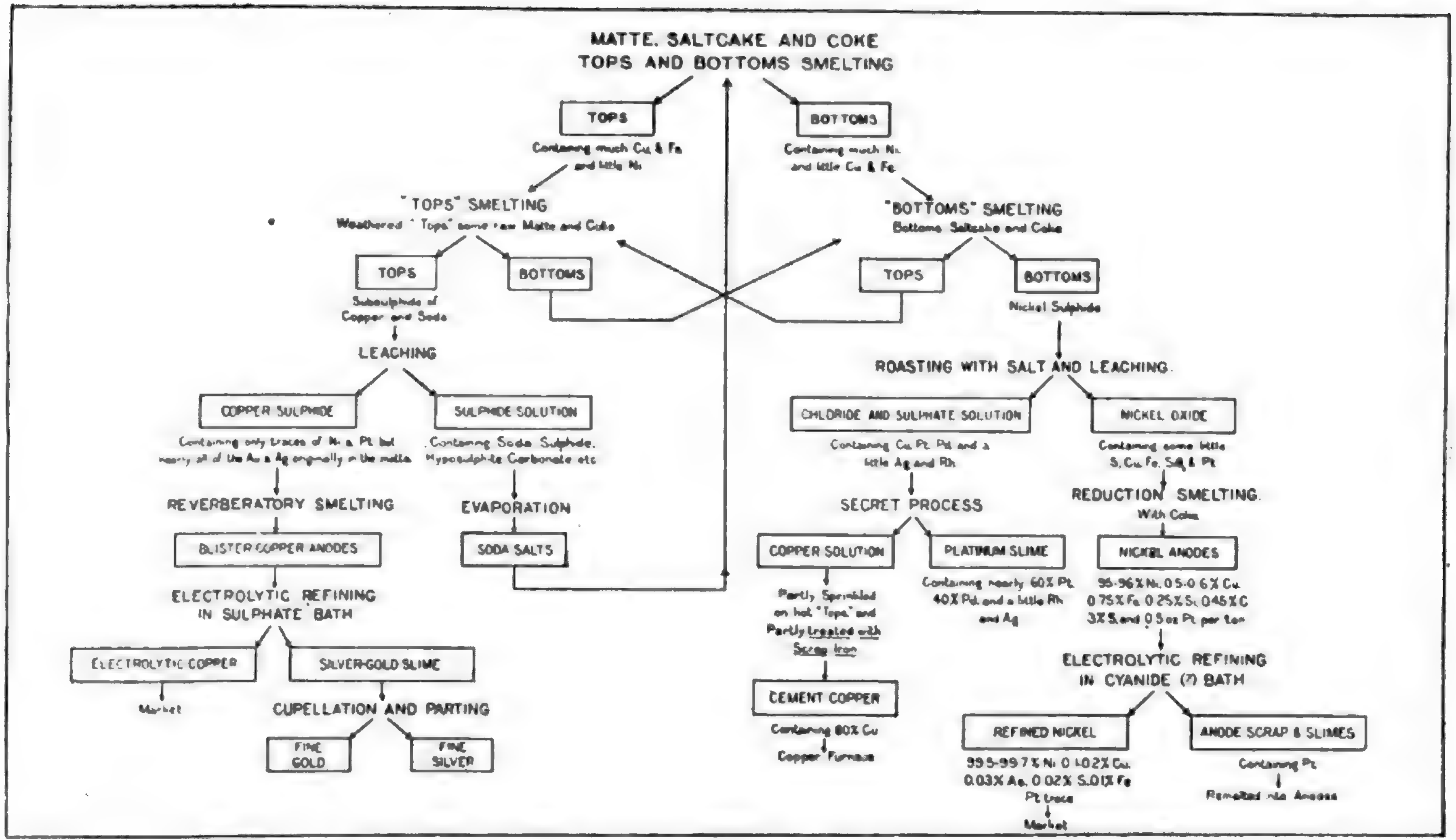
* Eng. and Min. Jour., Vol. LXIV., July 1897, pp. 8-9.

† Roberts-Austen 'Nickel Extraction by the Mond Process.' a paper read before the Institution of Civil Engineers, London, Eng., on the 8th November, 1898. Also Ann. Rep. Bur. of Mines, Ont., Vol. VIII., 1899, pp. 106-120.


MATTE, SALTCAKE AND COKE
TOPS AND BOTTOMS SMELTING
TOPS
Containing much Cu & Fe and little Ni
BOTTOMS
Containing much Ni and little Cu & Fe
"TOPS" SMELTING
Weathered "Tops" some raw Matte and Coke
"BOTTOMS" SMELTING
Bottoms Saltcake and Coke
TOPS
Subsulphide of Copper and Soda
BOTTOMS
TOPS
BOTTOMS
Nickel Sulphide
LEACHING
COPPER SULPHIDE
Containing only traces of Ni & Pt but nearly all of the Au & Ag originally in the matte
SULPHIDE SOLUTION
Containing Soda Sulphide, Hyposulphite Carbonate etc
REVERBERATORY SMELTING
EVAPORATION
BLISTER COPPER ANODES
SODA SALTS
ELECTROLYTIC REFINING IN SULPHATE BATH
ELECTROLYTIC COPPER
Market
SILVER-GOLD SLIME
CUPELLATION AND PARTING
FINE GOLD
FINE SILVER
ROASTING WITH SALT AND LEACHING.
CHLORIDE AND SULPHATE SOLUTION
Containing Cu Pt Pd and a little Ag and Rh
NICKEL OXIDE
Containing some little S, Cu, Fe, SiO₂ & Pt
SECRET PROCESS
COPPER SOLUTION
Partly Sprinkled on hot "Tops" and Partly treated with Scrap Iron
PLATINUM SLIME
Containing nearly 60% Pt 40% Pd and a little Rh and Ag
REDUCTION SMELTING
With Coke
NICKEL ANODES
95-96% Ni, 0.5-0.6% Cu, 0.75% Fe, 0.25% Si, 0.45% C, 3% S and 0.5 oz Pt per ton
CEMENT COPPER
Containing 80% Cu
Copper Furnace
ELECTROLYTIC REFINING IN CYANIDE (?) BATH
REFINED NICKEL
99.5-99.7% Ni, 0.1-0.2% Cu, 0.03% As, 0.02% S, 0.01% Fe, Pt trace
Market
ANODE SCRAP & SLIMES
Containing Pt
Remelted into Anodes

DIAGRAMMATIC SCHEME OF THE ORFORD METHOD OF TREATING NICKEL-COPPER MATTE.

to obtain a fresh charge of nickel. It has been stated that Dr. Mond's process, although ingeniously and thoroughly worked out, has developed certain weaknesses, such as imperfect extraction of nickel, and the necessity of repeating certain of the operations several times before satisfactory results are achieved and the larger proportion of the nickel obtained. The danger of explosion and poison from the carbon monoxide gas have all, seemingly, combined to delay the successful operation of this process on a large scale for any protracted period.

THE HOEPFNER ELECTROLYTIC PROCESS.

In this process, a chloride solution is obtained which has been freed from other metals, either chemically or electrolytically. The solution is neutralized and then acidulated with some weak oxygen acid, such as citric or phosphoric acid, and the electrolysis effected with insoluble anodes. The anodes are immersed in a chlorite solution of some more electro-positive metal than nickel. The cathodes are rotating or vibrating metal plates. The chlorine evolved is collected.

THE FRASCH ELECTROLYTIC PROCESS.

This process depends on the reaction in the electrolytic decomposition of common salt. At the anode chlorine is evolved, at the cathode sodium hydrate is formed by a secondary reaction. When applied to copper-nickel matte the anode consists of a layer of carbonaceous material. This is covered with a layer of matte, and the matte with a layer of sand, which serves as a diaphragm between the anode and cathode sections. The chlorine evolved dissolves the metals of the matte, forming chlorides. The solution is treated for the contained metals by electrolysis or chemically. From the solution of sodium hydrate at the cathode caustic soda is obtained.

BROWNE'S ELECTROLYTIC PROCESS.

In this process (1) the copper is first deposited from a solution of the mixed chlorides, using cathodes of pure copper and soluble anodes of copper-nickel alloy. The original percentage of metal chloride in the electrolyte is maintained partly by the solution of the anode, and partly by passing the electrolyte through a tower filled with bessemer matte or alloy to be treated in contact with the chlorine gas evolved at the anode by the nickel precipitation.

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(1) Min. Industry, Vol. X., 1901, p. 497.

When the electrolyte is rich in nickel and nearly all the copper is deposited the remaining copper is precipitated with hydrogen sulphide or a similar re-agent, and the iron with ammonia. The nickel chloride solution is then electrolyzed, using cathodes of pure nickel and anodes of carbon, in water-sealed compartments, from which the chlorine is conducted to the regenerating tower.

ULKÉ'S ELECTROLYTIC PROCESS.

In this process (²) a sulphate solution of the metals is used, instead of a chloride solution, as in the three processes described above.

'With the Ulké process it is most advantageous to use a material consisting of not over 20 per cent of nickel, and not less than 80 per cent of copper, which is cast into anode plates. The electrolyte consists of a solution of copper and nickel sulphate, and contains an excess of free-sulphuric acid, and the cathodes are of pure sheet copper. The electrolyte is heated and kept in circulation, and from time to time portions of it are withdrawn from the electrolytic vats to be re-standardized. The electrolyte withdrawn is replaced with an equal volume of copper sulphate solution, containing an excess of free acid to re-standardize the electrolyte. A portion of this copper sulphate is obtained as a by-product in the extraction of the nickel, as is outlined later in the description. The copper is precipitated (from withdrawn electrolyte) with hydrogen sulphide, and after filtering the copper sulphide precipitate is treated with sulphuric acid and heat to recover the hydrogen sulphide and make the by-product copper sulphate. The nickel sulphate is made ammoniacal, and used hot as an electrolyte for the precipitation of nickel, using anodes of lead and cathodes of sheet nickel. To avoid impoverishment of this electrolyte, portions of it are periodically withdrawn, the ammonia recovered for re-use and the nickel sulphate added to the electrolyte as needed to preserve the proper strength. The process is economical and produces nickel of high quality continuously and cheaply.'

Another process for the electrolytic winning of nickel which is in successful operation is the Balbach process, as carried on at the Balbach works, N.J. This process, however, is kept strictly secret.

NICKEL.

Nickel is a comparatively new metal, as far as our western civilization is concerned, for it was discovered in 1751 by the Swedish metallurgist Cronstedt. It was, however, not until 1754 that Cron-

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(2) Min. Industry, Vol. X., 1901, pp. 497-498.

stedt definitely determined that it was a new element. Its name was given on account of its being a constituent of niccolite or 'kupfernickel,' as it was then called. Cronstedt's discovery was made in examining the ore obtained from the mines of Helsingland. In 1776, Engstrom analyzed the material which had found its way to Europe from China under the name of 'Pachfong,' finding it an alloy made up of variable quantities of copper, nickel and zinc, but usually present in the proportion of 40 per cent of copper, 15 per cent of nickel and 45 per cent of zinc. This alloy had been in use in China for thousands of years. Previous to this again, as noticed by Dr. Austen in his 'Historical Sketch of Nickel,' the Bactrian King Eutheydemos, who reigned about 235 B.C., employed an alloy of nickel for coinage purposes, containing 77·58 per cent of copper, 20·04 per cent of nickel and 1·72 per cent of other impurities, such as iron, cobalt, tin, silver and sulphur. It is worthy of remark that so long after this the alloy at present in use for the manufacture of coins is very similar in composition, containing about 75 per cent of copper and 25 per cent of nickel, which experience has taught us is the best proportion for such a purpose.

Nickel, in its pure state, is silver-white in colour, hard, tough, fusible with difficulty, and is susceptible to magnetism, although not to the same extent as iron. It has the peculiar property of losing this magnetism when heated, and regaining it when cooled, this peculiarity being taken advantage of in the manufacture of certain alloys for electrical purposes. Nickel has a specific gravity of 8·5 to 8·9.

The purity of the nickel which has been on the market has steadily increased since its first manufacture. This will be evident from the subjoined table of analyses of the commercial product. The three first analyses are quoted from the Mineral Industry and were made in 1891. All the others were made in 1898 and 1899.

TABLE OF ANALYSES OF THE NICKEL OF COMMERCE.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Nickel	97.63	97.44	97.38	98.89	98.80	98.80	99.80	99.82	99.43	98.76
Cobalt	1.19	trace	1.70	0.14			none			
Iron	0.75	0.301	0.06	0.43	0.60	0.60	0.13	0.10	0.43	0.91
Copper	0.15		0.68	0.10	0.11		none			0·10
Sulphur	0.04	0.104	0.013		0.016	0.016	0.006	0.0068	0.0099	trace
Carbon				0.40	0.16	0.16	0.05	0.07	0.087	
Silicon				0.02	0.09	0.09	none			0.26
Manganese				0.02						
Tin					0.11					
Arsenic					0.11	0.11				none
Insoluble									0.026	
Carbon, Silicon, &c.	0.24	0.2155	0.167							

Analysis	I.	Rolled nickel anode (German); F. P. Dewey, analyst, 1891.
"	II.	Cast nickel, Gard, analyst 1891.
"	III.	Disk nickel; F. P. Dewey, analyst, 1891.
"	IV.	American nickel; by Forester, quoted by Ulké, Min. Ind. Vol VI, p. 595.
"	V.	Cubes; Ferro-nickel Co., Inst. Civil Eng., London, Eng., March 28, 1899.
"	VI.	Thompson nickel; Inst. Civ. Eng. London, Eng., Mar. 28, 1899.
"	VII.	Mond nickel; Inst. Civ. Eng. London, Eng., Mar. 28, 1899.
"	VIII-IX.	Mond nickel; Inst. Civ. Eng. London, Eng. Nov. 8, 1898.
"	X.	Wharton nickel; by J. W. Bain, Ann. Rep. Bur. of Mines, Ont. 1900, p. 223.

USES.

The first and chief demand for this metal was for making nickel or German silver, as a substitute for the more precious metal, in the manufacture of spoons, forks and other ware in general use for which silver had been previously used. Its whiteness, and the facility with which it received and held the silver, after the process of electroplating was introduced, has caused it to be still more widely used. This use, however, has been replaced in a large degree by plating iron with nickel, which gives a very similar effect to German silver.

Nickel is also used very extensively for coinage purposes, both in Europe and America, these coins generally consisting of an alloy of from 75 to 88 per cent of copper and 12 to 25 per cent of nickel. Recently both Austria and Switzerland have authorized the use of pure nickel in coins.

Pure nickel is now used in making small articles which formerly were only electroplated with nickel. An alloy, with 20 per cent of nickel and 80 per cent of copper, is used for casing bullets. This alloy has a higher degree of tenacity than the best brass, and a high co-efficient of elongation.

Owing to the intense colouring properties of nickel, (it is greater than that of any other metal except tin), these alloys have almost the same colour as the pure nickel.

In far more general use are the nickel-copper-zinc alloys. These were first introduced into Europe from China, in the eighteenth century, under the name of Packfong or China silver, and it was only later that it was discovered that they consisted of nickel, copper and zinc. As European firms began to use these alloys for manufacturing purposes they gave them various names, such as german silver, argentan, etc.

The following are analyses, from Ledebur's 'Technologie,' of some of these alloys:

——	Copper.	Zinc.	Nickel.	Iron.
English new silver	63·34	17·01	19·13	0·52
Vienna "	55·60	22·20	22·20	......
French "	50·00	31·25	18·75	......
" "	59·10	30·20	9·70	1·00
" "	69·90	5·60	19·80	4·70

The chief uses of these alloys are for forks, spoons, etc., and various household goods to be silver-plated, and for many scientific instruments where brass was formerly used.

A little magnesium added to nickel when in a molten state increases its malleability, and this property has been utilized in the manufacture of nickel into sheets, and also in making sheets composed of an iron plate, with a nickel plate welded upon each side of the iron; the mass then becoming capable of being rolled into any desired thickness. This rolled nickel plate is an advance over the ordinary tin plate for culinary and other utensils.

Nickel-plated zinc or 'nickeloid,' as it is called, is being used to a considerable extent in the manufacture of reflectors, refrigerator linings, baths, etc.

The most important and extended use of nickel, however, is in the manufacture of nickel steel, and, at present, we must look to its more general employment in this direction, as replacing carbon and manganese steel, for the development of the nickel industry. The peculiar and desirable behaviour of nickel in alloy with other metals, and especially with iron and steel, has often been remarked, the material partaking more of a chemical combination than an ordinarily intimate mixture. All these alloys are remarkably homogeneous, and susceptible of a high polish, though rather difficult of manipulation. In obtaining a correct idea of the usefulness or value of alloys of nickel with iron and steel it should be borne in mind that these mixtures contain manganese, carbon, silicon, sulphur and phosphorus, whose influence may be carefully watched, requiring a long series of experiments. A comparison of steel alloyed with 4·7 per cent of nickel raised the elastic limit from sixteen up to twenty-eight tons, and the breaking strain from thirty up to forty tons, without impairing the elongation or contraction of area to any appreciable extent. A further gradual increase of hardness is noticed until 20 per cent is reached, when a change takes place, and successive additions of nickel tend to make the steel softer and more ductile. The alloys polish well, and the colour of the steel is lightened as the proportion of nickel is increased. They do not corrode as readily as other steel. The one per cent nickel steel welds fairly well, but this property lessens with each addition of nickel. It may, therefore, be said that considerable advantage can be expected from these alloys, especially where the amount of nickel present is less than 5 per cent. Nickel steel is now being used for a variety of purposes, among which may be mentioned rails for railways. These have been tried for a number of years at Cumberland Gap in the United States, and have given very great satisfaction. The first cost is considerably higher, but they can be

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made much lighter, and will outlast three ordinary steel rails. Its most important use, however, is for armour plates and heavy ordnance. For machine parts, subjected to alternate stress and shock, and where increase of strength and decrease of weight are desired, it is unrivalled. On account of this marked quality it has been used for engine and propeller shafts, and has proved so superior to all other steel for this purpose that it has no rival of importance. Owing to its resistance to 'fatigue' from persistent vibration and concussion it is particularly valuable for steam hammer piston rods, rock drill piston rods, railway axles or tank pins; also for light forged engine frames, bolts for extreme hydraulic pressure, bicycles, etc. It has also been recommended for the manufacture of dies and shoes in stamp mills, and of wire rope. Nickel steel wire rope would be less corrosive and have more tensile strength than the ordinary steel wire ropes in use at present.

The co-efficient of expansion of nickel steel with 36 per cent of nickel is only 0·00000087, that of ordinary materials varying from ten to twenty times this figure. This low co-efficient of expansion will likely be of great value for many purposes. Alloys with 42 to 46 per cent of nickel have the same co-efficients of expansion as the various sorts of glass, which will make them valuable in replacing the more expensive platinum in cases where metal and glass have to be welded together.

Other alloys of nickel are mentioned in 'The Mineral Industry,' Vol. X. They are nickel-aluminium, with a tensile strength of 40,000 pounds per square inch, and an elastic limit of 35,000 pounds per square inch.

Chrome nickel, containing usually 73 per cent of chromium, 23 per cent of nickel, 2·5 per cent of iron, 1 per cent of carbon and 0·5 per cent of silicon, is used for making steel for projectiles and armour plates, which is said to be better than Harveyized steel armour plates. Tungsten-nickel has a composition similar to chrome-nickel, tungsten taking the place of chrome.

Molybdenum-nickel with 45 to 75 per cent of molybdenum, 20 to 50 per cent of nickel, 2 to 2·5 per cent of iron, 1 to 1·5 per cent of carbon and 0·25 to 0·50 per cent of sulphur, is largely used in the manufacture of forgings, guns, wire, boiler-plate and shells.

The era of nickel steel has only been entered upon, for it was not until 1888 that this desirable alloy was made on any scale of commercial importance. Canada has the largest supply of the most desirable nickel ores in the world, and the quality of the metallic nickel, as shown by the analyses quoted, is of a very high degree of purity. It is beyond the scope of the present report to enter upon a discussion of the manifold merits of nickel steel, and the numerous benefits to be derived from its use. In 1899, Messrs. R. A. Hadfield (1) and David H. Browne (2), published two very complete contributions on this subject, and the reader may have reference to these for more detailed information. Lately, Dr. Waddell has been employed, under the auspices of the International Nickel Company, in making an elaborate series of tests and experiments with nickel steel, with special reference to its more extended use in bridge building. The general public, and more particularly that numerous section of it in Canada who are interested in the extension of the nickel industry, will look forward with pleasure to the appearance of Dr. Waddell's conclusions, which, it is hoped, will not be withheld on the plea that the information is of a confidential nature.

PRODUCTION OF NICKEL AND COPPER FROM THE SUDBURY DISTRICT.

It is difficult to obtain the exact production of the nickel and copper ores of the Sudbury district during the first three years of mining, from 1886 to 1888, inclusive. Thus, R. R. Maffett, Superintendent of the Orford Copper Company, at New Brighton, L.I., N.Y., under date of April 18, 1904, answering an inquiry addressed to President A. P. Turner, of the Canadian Copper Company, at Copper Cliff, Ont., states, that during 1886, 1,040 tons of ore, carrying 7·2 per cent of copper and 3 per cent of nickel, were mined at Copper Cliff, and during 1887, 8,864 tons carrying 8·56 per cent of copper and 3·31 per cent of nickel, were also raised from the same mine. According to details furnished the Geological Survey Department by the Customs Department, 3,307 tons of copper ore were shipped form Sudbury in 1886, with a declared customs value of $16,404, and in 1887, 567 tons of similar ore were also shipped, with a declared customs value of $3,416. A careful and conservative estimate to arrive at the total production would place the amount mined during these three years at 30,000 tons, averaging about 5 per cent of copper and 3 per cent of nickel, this ore thus containing, approximately, 900 tons of nickel and 1,500 tons of copper. Valuing the nickel at the average price for the three years, at 62·12 cents per pound, the total ultimate value of the nickel in the ore would amount to $1,118,160, while the copper, at the average price of twelve cents per pound, would amount to $360,000. According to the yearly returns furnished the Geological Survey Department and the Ontario Bureau of Mines, the total ore mined in the district, including the estimate as above given for the first three years, has amounted to 2,093,427 tons. The total amount of nickel in matte, sold from 1889 to 1903, both years inclusive, amounted to 39,827 tons, with a final value in New York, at the lowest average prevailing price in the year in which it was placed upon the market, amounting to $35,603,272, while the copper present in the matte, in the same period, amounting to 37,429 tons, valued at the average price of copper in the year sold, realized $9,799,730. If we include the three first years, at the figures already given, we obtain a total amount of nickel sold of 40,727 tons, with a value of $36,721,432; while the copper amounted to 38,929 tons, with a value of $10,159,739.

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(1) Proc. Inst. Civil Eng., London, Vol. cxxx., pp. 1-167.

(2) Trans. Am. Inst. Min. Eng., Vol. xxix., (Sept.), 1899, pp. 569-648.

This nickel and copper ore also contains cobalt, and an average of a large number of assays would indicate that the proportion of nickel to cobalt as 50 to 1 is a conservative estimate. If all of this could have been saved, 815 tons of cobalt would have been thus produced, and this, at a price of $3 per pound, would have amounted to $4,890,000. In addition, these ores contain appreciable quantities of the precious metals, gold, silver and metals of the platinum group. The platinum metals average about 1·25 ounces, the gold 0·375 of an ounce, while the silver has been calculated on the assumption that 7·5 oz. are present to the ton of nickel, which is certainly below the average. On this assumption, the value of the precious metals, at the average of the ruling New York price in the years produced, would be as follows: Gold, $305,460; Silver, $195,286; Platinum, $805,429; Total, $1,306,175. The total ultimate value in New York of the various metals contained in these ores, would, therefore, be as follows:

Nickel	$36,721,432
Cobalt	4,890,000
Copper	9,799,739
Gold	305,460
Silver	195,286
Platinum	805,429
Total	$52,717,346

Of the total production of ore, about four-fifths must be credited to the Canadian Copper Company. This company does not wish, at present, to give the production of each individual mine, but through the courtesy of President A. P. Turner of the Canadian Copper Company, I am authorized to state that the three largest of their mines have produced the following amounts of ore, up to the first of June, 1904.

Stobie mine	419,000 tons.
Copper Cliff mine	366,000 "
Creighton mine	310,000 "

Some of the other mines have also produced large quantities of ore, as the Evans mine, No. 2 and No. 3 (Frood) mines, all three of which have produced between 100,000 and 200,000 tons of ore. The Creighton mine is, without doubt, the largest mine in the district, and is regarded as capable of producing many millions of tons of high grade ore. The ore at present being mined averages about 5 per cent of nickel and 2 per cent of copper. During the month of May last (1904) 19,000 tons of ore were mined, and, in June, it was expected that 22,000 tons would be secured. It is proposed in the near future to erect another rock house farther west on this same deposit, when the output will be nearly doubled. The old Blezard mine, belonging to the Dominion Mineral Company, probably produced about 100,000 tons of ore, while 25,000 tons seems a reasonable estimate for that produced by the Worthington mine. The Victoria mine, belonging to the Mond Nickel Company, has produced about 80,000 tons of ore, while the same company, up to the 1st of June, 1904, had obtained about 13,000 tons from the North Star mine. At the Murray mine, 62,193 tons were produced, while the Lake Superior Power Company obtained 33,835 tons from the Elsie mine, and 18,000 tons from the Gertrude mine, up to the end of 1903.

The following tables are reproduced from the annual reports of the Division of Mineral Statistics and Mines of the Geological Survey Department, and of the Bureau of Mines, of Ontario. Both have been prepared by Mr. J. McLeish, who has charge, under Mr. E. D. Ingall, of this branch of the work. They will show, in a diagrammatic manner, the details of the mining operations carried on in the district from 1889 to 1903, both years inclusive.

Production of Nickel and Copper, Sudbury district, Ontario, according to the Mines Section, Geological Survey.

Calendar Year.	Ore mined.	Ore treated.	Ordinary matte sold and shipped	High grade matte sold and shipped.	Spot value of matte.	Nickel contents of matte sold.	Final value of nickel.	Copper contents of matte sold.	Final value of copper.
	Tons.	Tons.	Tons.	Tons.	$	Tons.	$	Tons.	
1886	3,307	30,000?							
1887	567					900?	1,118,160?	1,500?	360,000?
1888									
1889	44,990	40,146	3,274			432	518,602	733	201,678
1890						718	933,232	651	205,233
1891	83,300	72,558	10,336			2,018	2,421,208	2,064	531,234
1892	74,381	57,022				1,207	1,399,956	1,102	254,538
1893			9,425			1,991	2,071,151	1,821	391,461
1894	103,223	96,038	11,681		766,422	2,454	1,870,958	2,604	497,854
1895	74,135	68,618	10,188		890,834	1,944	1,360,984	2,288	492,414
1896	94,966	71,027	10,759		416,594	1,699	1,188,990	1,584	344,598
1897	93,154	96,370	13,968			1,999	1,399,176	2,750	621,023
1898	123,820	121,924				2,759	1,820,838	4,187	1,007,539
1899	159,957	172,761			702,341	2,872	2,067,840	2,834	998,135
1900	196,420		23,336		1,076,306	3,540	3,327,707	3,364	1,089,383
1901	315,692	255,958			1,661,839	4,594	4,594,523	4,318	1,392,018
1902	269,538	211,847	23,211	2,100	1,327,448	5,347	5,025,903	3,553	826,175
1903	136,033	207,030		13,832	2,686,469	6,253	5,002,204	3,576	946,456

Production of Nickel and Copper, Sudbury district, Ontario. Compiled from the Annual Reports of the Ontario Bureau of Mines.

Year.	Ore raised.	Ore smelted.	Ordinary matte produced.	High grade matte produced.	Spot value of matte.	Per cent of Ni and Cu contents in ore smelted.		Ni contents of matte.	Cu contents of matte.	Cobalt.	Spot value of nickel in matte.	Spot value of copper in matte.	Spot value of cobalt in matte.	Wages paid.	Men employed.
	Tons.	Tons.	Tons.	Tons.	$	Ni.	Cu.	Tons.	Tons.	To's	$	$	$	$	
*1890	130,278	59,329	....	....	....	......	......	....	....	....	....	....	....	....	....
*1891	85,790	71,480	....	....	....	......	......	....	....	....	....	....	....	....	....
*1892	72,349	61,924	6,278	1,880	826,750	3.362	3.126	2,080	1,936	8½	590,902	232,135	3,713	339,821	690
*1893	64,043	63,944	7,176	452	539,302	2.585	2.237	1,653	1,431	19	445,702	115,200	9,400	252,516	495
*1894	112,037	87,916	10,410	1,470	809,974	2.924	3.125	2,570¼	2,748	3¼	612,724	195,750	1,500	311,719	655
*1895	75,439	86,546	12,525	103	565,774	2.675	2.733	2,315⅝	2,365⅞	....	404,861	160,913	....	209,960	444
1896	109,097	73,505	9,733	....	487,660	2.651	2.534	1,948½	1,868	....	357,000	130,660	....	247,151	485
†1897	93,155	96,094	13,706	328	559,718	2.080	2.861	1,999	2,750	....	359,851	200,067	....	253,226	535
†1898	123,920	121,924	21,101	....	782,300	2.283	3.433	2,783¾	4,186¾	....	514,220	268,080	....	315,501	637
†1899	203,118	171,230	19,109	106	702,340	1.677	1.655	2,872	2,834	....	526,104	176,236	....	443,879	839
†1900	216,695	211,960	23,336	112	1,076,307	1.670	1.587	3,540	3,364	....	756,626	319,681	....	728,946	1,444
†1901	326,945	270,380	29,588	15,546	2,449,050	1.642	1.552	4,441	4,197	....	1,859,970	589,080	....	1,045,889	2,284
1902	269,538	233,388	24,691	13,332	2,827,724	2.547	1.742	5,945	4,066	....	2,210,961	616,763	....	835,050	1,445
1903	152,940	220,937	30,416	14,419	3,082,714	3·167	1,812	6,998	4,005	....	2,499,068	583,646	....	746,147	1,277

* Year ending 31st October.
Year ending 31st December.

THE WORLD'S PRODUCTION OF NICKEL.

From 1840 to 1860 the annual production of nickel scarcely averaged 100 metric tons per annum, and in no single year was a production of 200 metric tons exceeded. From 1860 to 1880, a very gradual, though distinct, increase was noticeable, up to 600 metric tons, although about the year 1874 a little over 700 metric tons were produced. In 1880, the product of the New Caledonia mines became a distinct factor on the market, at first with a production of about 200 metric tons per annum, but gradually increasing until the year 1884, when the production was about 1,000 tons. In the year 1889, the product of the Sudbury mines was placed upon the market, but only 432 tons were sold. In the year 1891, however, 2,018 tons (1,830 metric tons) of nickel were sold, which had been produced from the Sudbury ores, while, at the same time, the product of the New Caledonia mines, which had reached the figure of 2,494 metric tons, dropped to 1,696 metric tons in 1892. In 1893 the world's total production of nickel amounted to 4,412 metric tons, the amount of the Canadian product placed on the market aggregating 1,807 metric tons; while Norway, in the same year, produced about 90 metric tons, and the United States 22·4 metric tons.

These figures showed a still further and rather rapid increase up to the year 1901, when a total of 9,381 metric tons was produced, the Canadian nickel amounting to 4,168 metric tons, and the New Caledonia to 5,210 metric tons, while the United States produced only three tons of nickel from domestic ores.

In 1902 the total of the world's production amounted to 8,473 metric tons, but of this Canada's share was 4,850 tons, while the New Caledonia output showed a decrease of 3,620 tons.

In 1903 the amount of Canadian nickel produced amounted to 6,348 metric tons, while New Caledonia produced only 4,750 metric tons.

The world's total production of nickel for 1903, as stated by the Metallgesellschaft, amounted to 9,850 metric tons. It is evident, however, that this is understated and that the actual production is considerably in excess of this amount, for the official returns for Canada and the United States, as reported to the Geological Survey and the Bureau of Mines of Ontario, give the production as 6,400 metric tons, instead of 5,100 metric tons, as stated by this authority. Assuming the official figures as more nearly accurate, and adding the production from New Caledonia as quoted by the Metallgesellschaft, (4,750 metric tons), a grand total of 11,150 metric tons is obtained as the aggregate of the world's production for 1903.

These figures are full of hope for Canada, and with the gradually increasing knowledge of the true value and uses of nickel, by reason of its many desirable physical qualities, which is gradually becoming more general, the production of nickel should be doubled in the next five years. It is hoped and confidently expected that Canada's share in this large output will be fully three-fourths of the whole.

The following table will show, at a glance, and in much greater detail, the world's annual production of nickel from 1889 to 1902. The figures for the foreign production for 1903 are not yet available.

These statistics are obtained mainly from the Metallgesellschaft and Metallurgische Gesellschaft (Frankfort-on-the-Main), Aug., 1903, p. 23.

The production of nickel from domestic ores in the United States is quoted from Mineral Resources of the United States, while that of Canada is from the Division of Mineral Statistics and Mines, Geological Survey of Canada, with the exception of 1903, which is from the Bureau of Mines. The figures of Canadian production include nickel actually sold, while those of the Bureau of Mines, which are stated in a separate table, are of nickel produced, part of which remained in stock.

The figures for Germany represent the production of Prussia. Saxony also produces nickel, but accurate details are not readily available.

THE PRICE OF NICKEL.

In 1876, the price of nickel per pound amounted to $2.60. In 1877 it dropped to $1.60 per pound and in 1878 it showed a still further decline to $1.10 per pound. In 1879, it recovered slightly to $1.12 per pound, but in 1880 it again decreased to $1.10, which latter figure was maintained until 1883, when the price steadily declined to about sixty cents. At present the price quoted by leading producers varies from forty to forty-seven cents per pound for large quantities down to ton lots, according to size and terms of order. The price for smaller lots, according to quantity, runs as high as sixty cents per pound in New York.

World's Production of Nickel (in metric tons).

<table>
<tr><th rowspan="2">Year.</th><th rowspan="2">Sweden and Norway.</th><th colspan="3">Nickel contents of ores exported from New Caledonia.</th><th rowspan="2">Total. (New Caledonia.)</th><th rowspan="2">Canada.</th><th rowspan="2">United States.</th><th rowspan="2">Grand total.</th><th rowspan="2">Average price per lb. in New York.</th></tr>
<tr><th>Germany.</th><th>France,</th><th>Great Britain.</th></tr>
<tr><td>1889</td><td>80</td><td>282</td><td colspan="2">1,050</td><td>1,332</td><td>377</td><td>114·606</td><td>1,904</td><td>60 c.</td></tr>
<tr><td>1890</td><td>100</td><td>434</td><td colspan="2">1,200</td><td>1,634</td><td>651</td><td>101·372</td><td>2,486</td><td>65 c.</td></tr>
<tr><td>1891</td><td>125</td><td>594</td><td colspan="2">1,900</td><td>2,494</td><td>1,830</td><td>53·750</td><td>4,503</td><td>60 c.</td></tr>
<tr><td>1892</td><td>97</td><td>746</td><td colspan="2">950</td><td>1,696</td><td>1,095</td><td>41·845</td><td>2,930</td><td>58 c.</td></tr>
<tr><td>1893</td><td>90</td><td>893</td><td colspan="2">1,600</td><td>2,493</td><td>1,807</td><td>22·407</td><td>4,412</td><td>52 c.</td></tr>
<tr><td>1894</td><td>90</td><td>522</td><td colspan="2">1,900</td><td>2,422</td><td>2,226</td><td>4·362</td><td>4,742</td><td>38⅛ c.</td></tr>
<tr><td>1895</td><td>40</td><td>698</td><td colspan="2">1,850</td><td>2,548</td><td>1,764</td><td>4·673</td><td>4,357</td><td>35 c.</td></tr>
<tr><td>1896</td><td>20</td><td>822</td><td>1,545</td><td>340</td><td>2,707</td><td>1,541</td><td>7·788</td><td>4,276</td><td>35 c.</td></tr>
<tr><td>1897</td><td>......</td><td>898</td><td>1,245</td><td>715</td><td>2,858</td><td>1,813</td><td>10.753</td><td>4,682</td><td>35 c.</td></tr>
<tr><td>1898</td><td>......</td><td>1,108</td><td>1,540</td><td>1,000</td><td>3,648</td><td>2,503</td><td>5·055</td><td>6,156</td><td>33 c.</td></tr>
<tr><td>1899</td><td>......</td><td>1,115</td><td>1,740</td><td>1,350</td><td>4,205</td><td>2,605</td><td>10·224</td><td>6,820</td><td>36 c.</td></tr>
<tr><td>1900</td><td>......</td><td>1,376</td><td>1,700</td><td>1,450</td><td>4,526</td><td>3,211</td><td>4·407</td><td>7,741</td><td>47 c.</td></tr>
<tr><td>1901</td><td>......</td><td>1,660</td><td>1,800</td><td>1,750</td><td>5,210</td><td>4,168</td><td>3·039</td><td>9,381</td><td>50 c.</td></tr>
<tr><td>1902</td><td>......</td><td>1,604</td><td>1,110</td><td>1,310</td><td>4,024</td><td>4,850</td><td>2·607</td><td>8,877</td><td>47 c.</td></tr>
<tr><td>1903</td><td>......</td><td>1,600</td><td>1,500</td><td>1,650</td><td>4,750</td><td>6,348</td><td>51.801</td><td>11,150</td><td>40 c.</td></tr>
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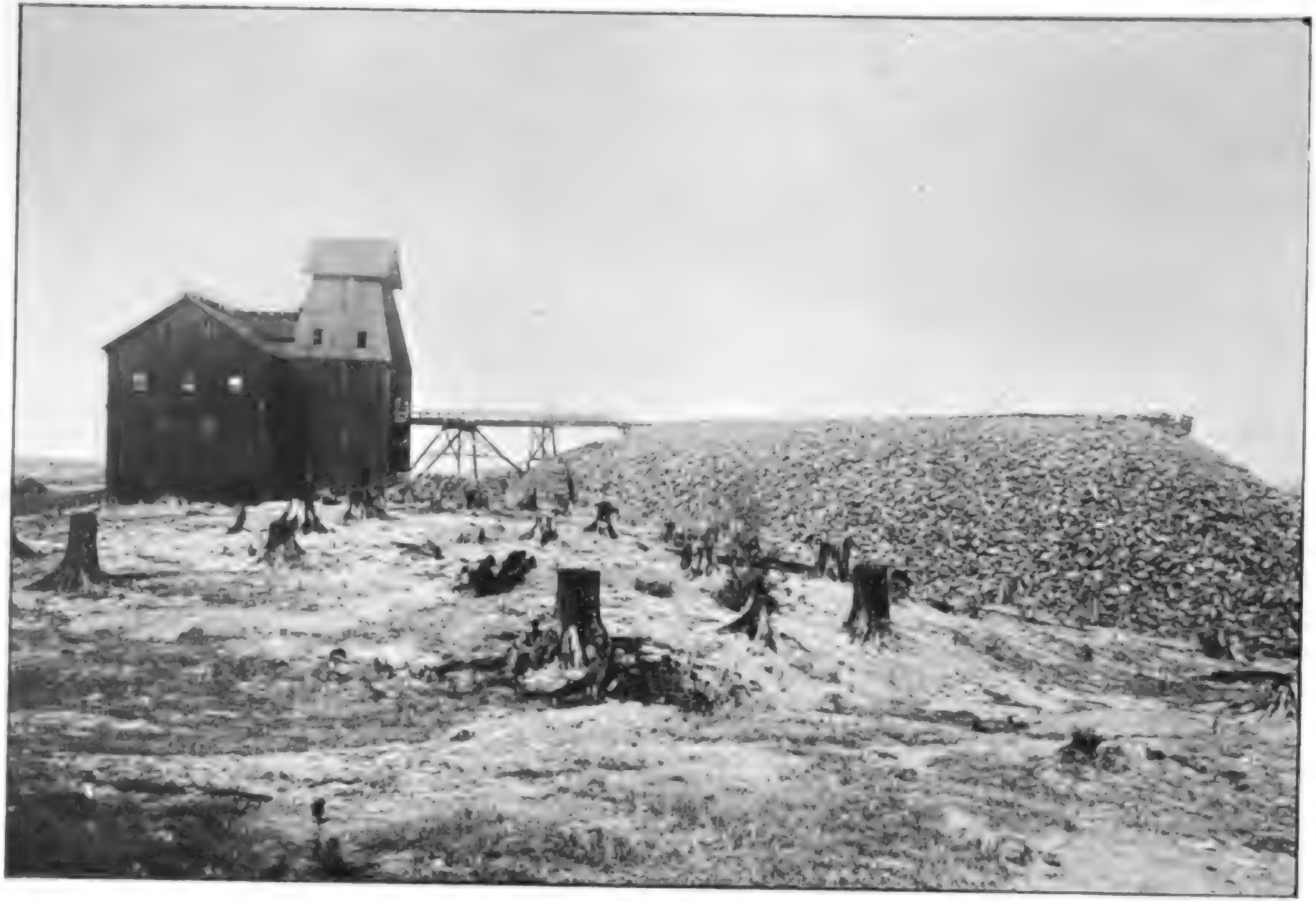

EVANS MINE, CANADIAN COPPER CO., COPPER CLIFF, ONT.

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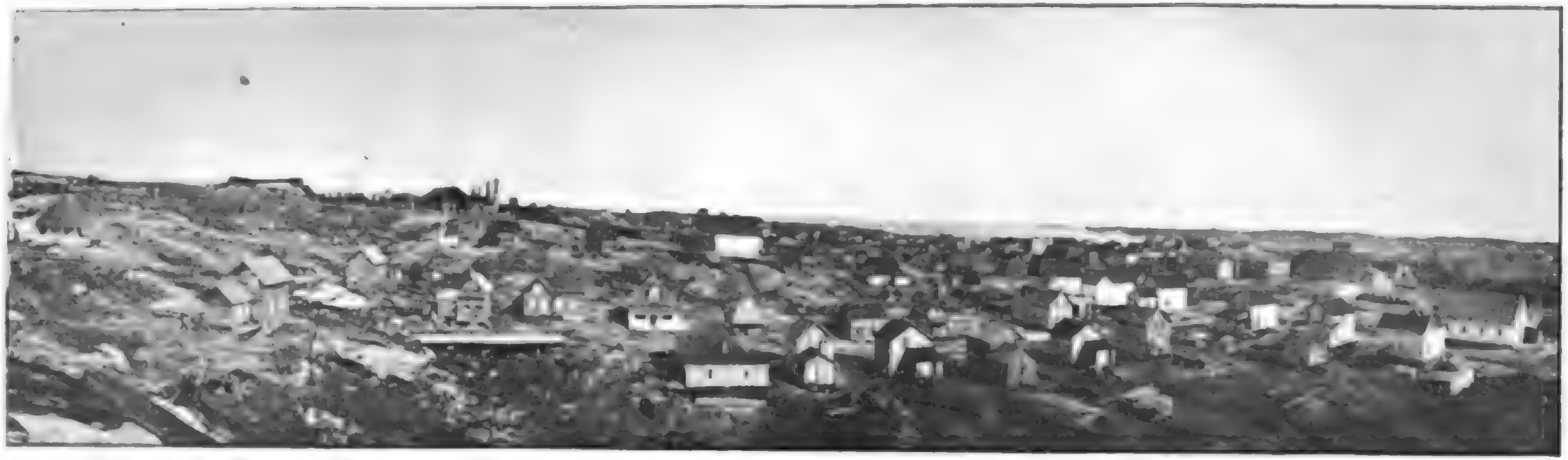
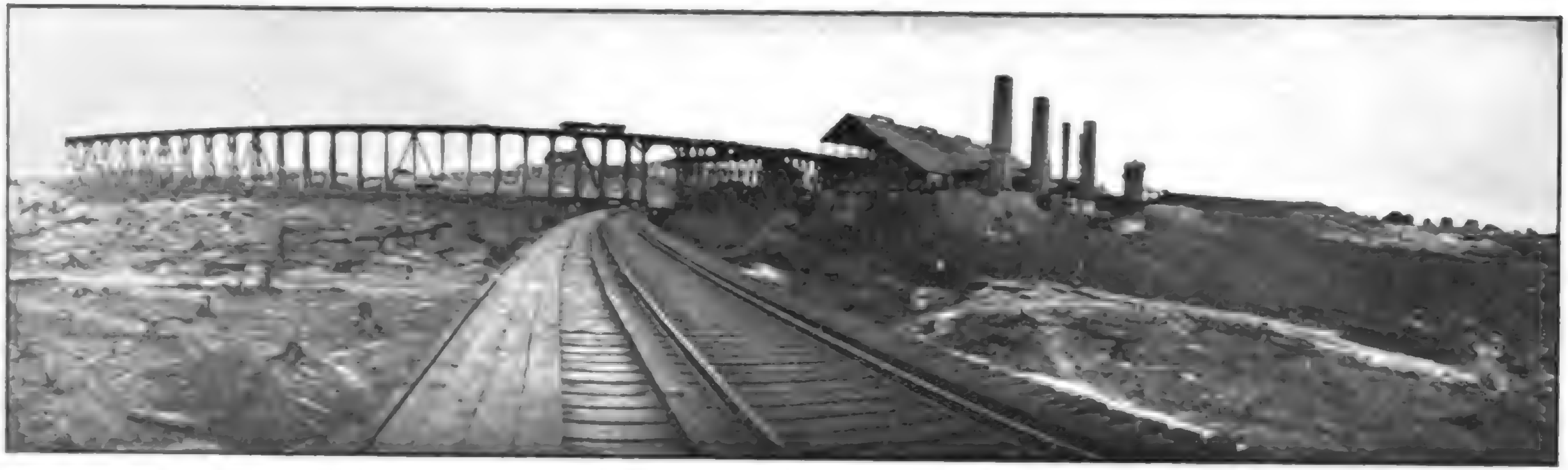


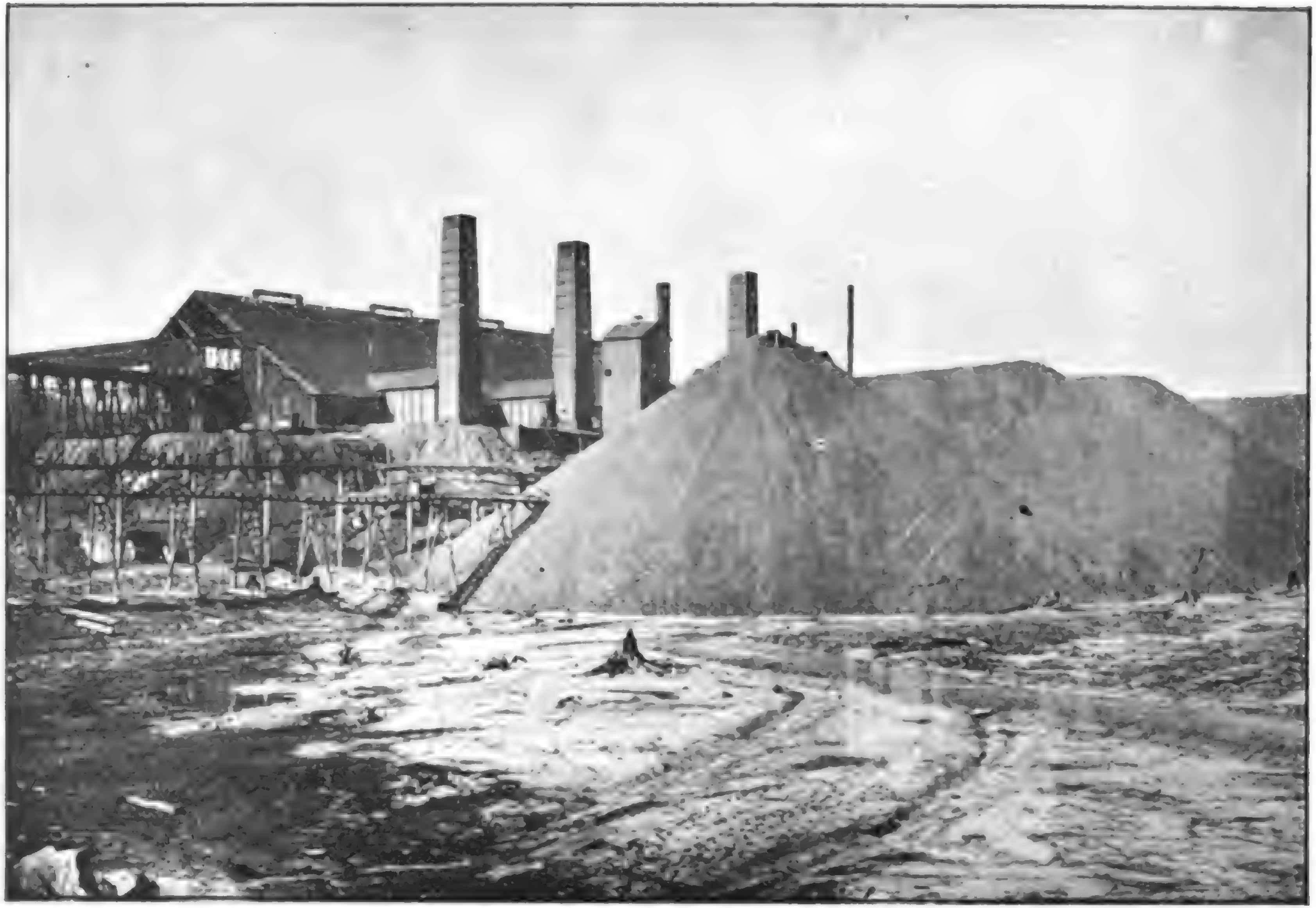
THE TOWN OF COPPER CLIFF, ONT.



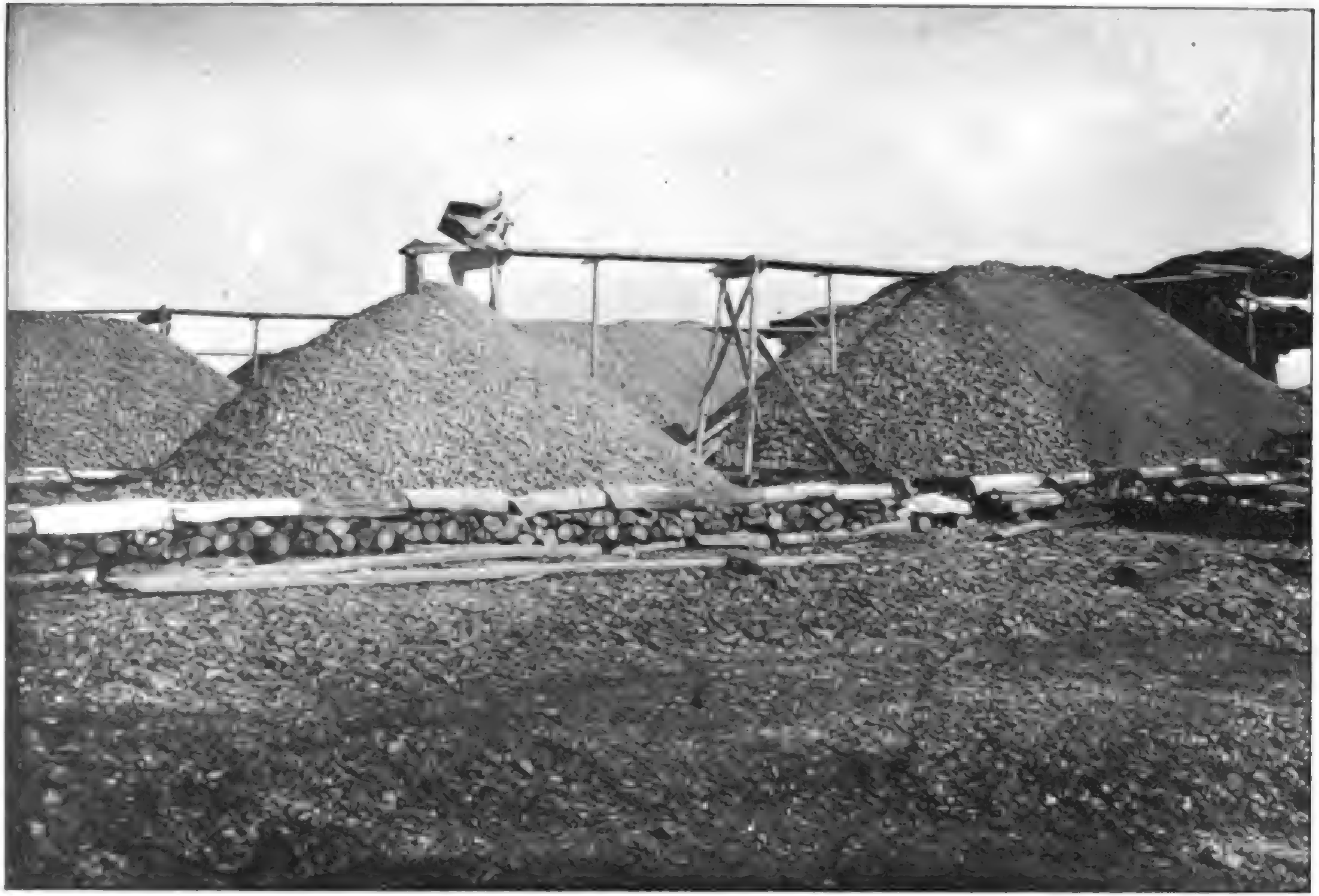
WEST SMELTER OF CANADIAN COPPER CO., AT COPPER CLIFF, ONT.

The Ontario Smelting Works, Orford Copper Co., at Copper Cliff, Ont.
These buildings were destroyed by fire in the spring of 1904.

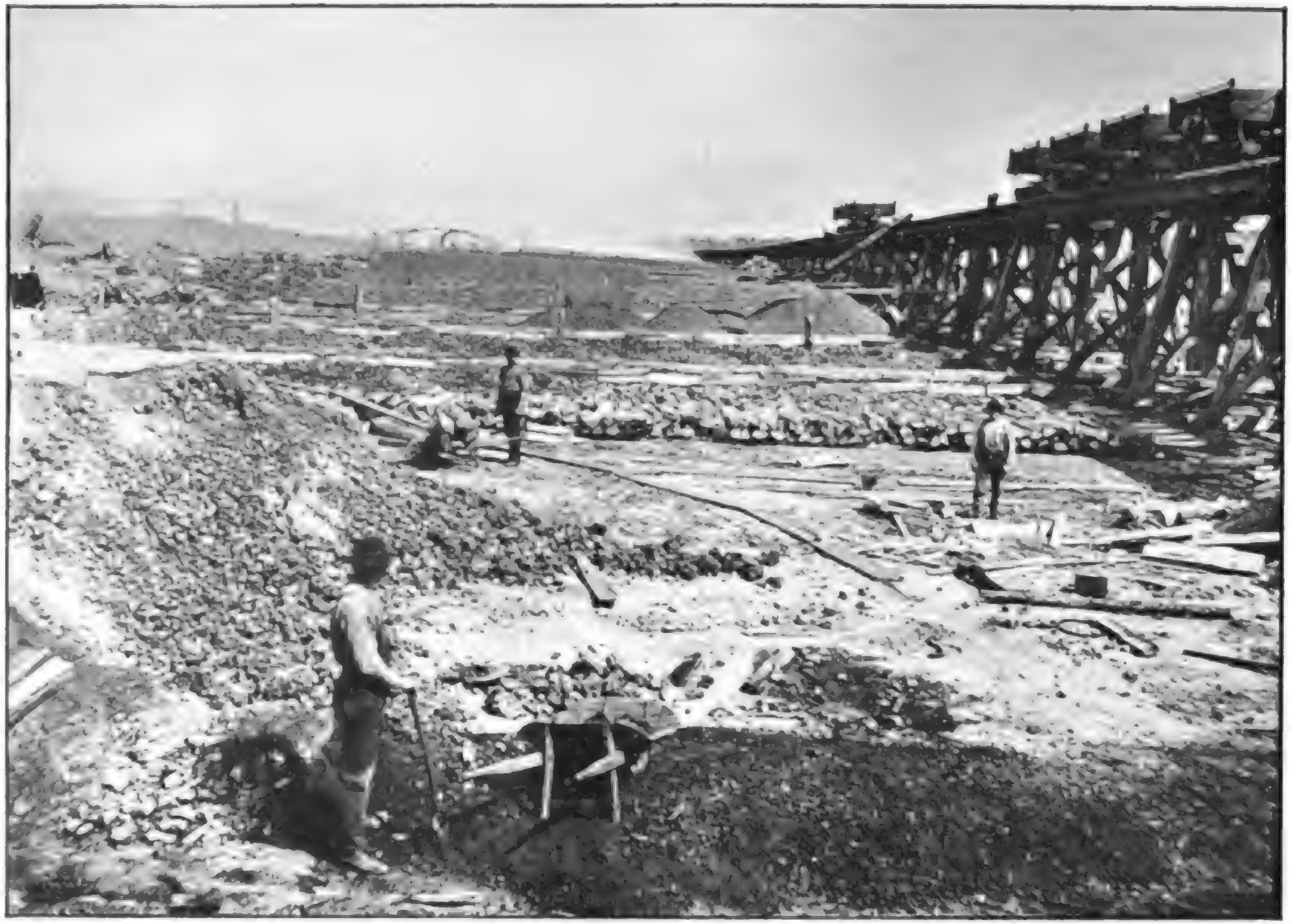
No. 2 Mine, West Smelter and Matte Shipping Yard, Canadian Copper Co., Copper Cliff, Ont.



The West Smelter of the Canadian Copper Co., at Copper Cliff, Ont.
This view looking N.E. was obtained from the high trestle leading from the lower roast yard. The high dumps of granulated slag are prominent in the foreground.



Roast yard at Copper Cliff, Ont.
Showing temporary trestle and general method of building roast heaps.



ROAST YARD OF THE CANADIAN COPPER CO., AT COPPER CLIFF, ONT.

In the foreground the ore is being removed from a pile that is roasted; the next pile shows the wood already laid to receive the ore, while in the background are similar ore piles in various stages of preparation for roasting. In the distance some of the piles are already fired with dense fumes arising from them, while to the right is the elevated railroad which runs the whole length of the yard.

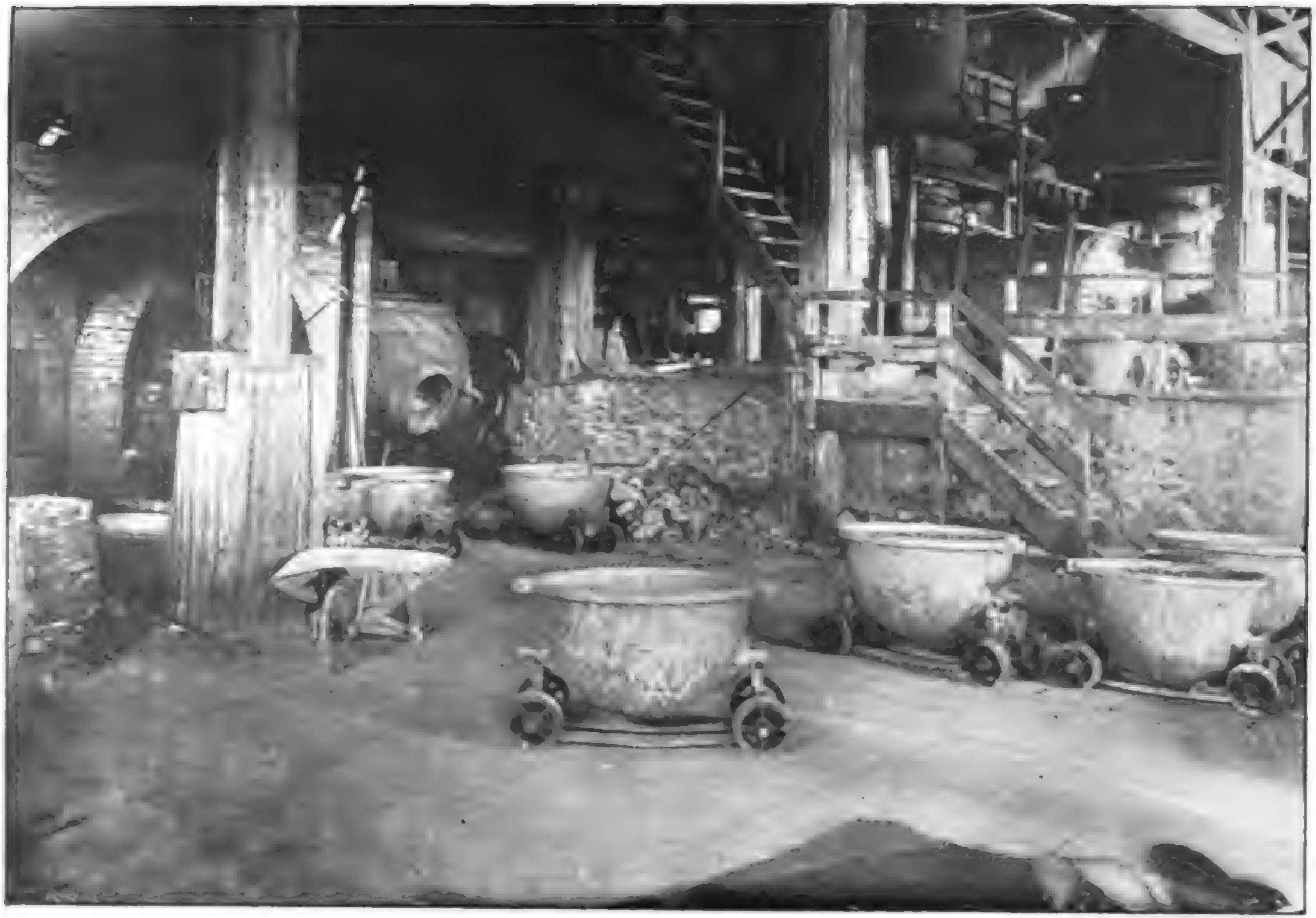
Roasting ore at main yard, Canadian Copper Co., at Copper Cliff, Ont.

Elsie Mine (Lake Superior Power Co.).

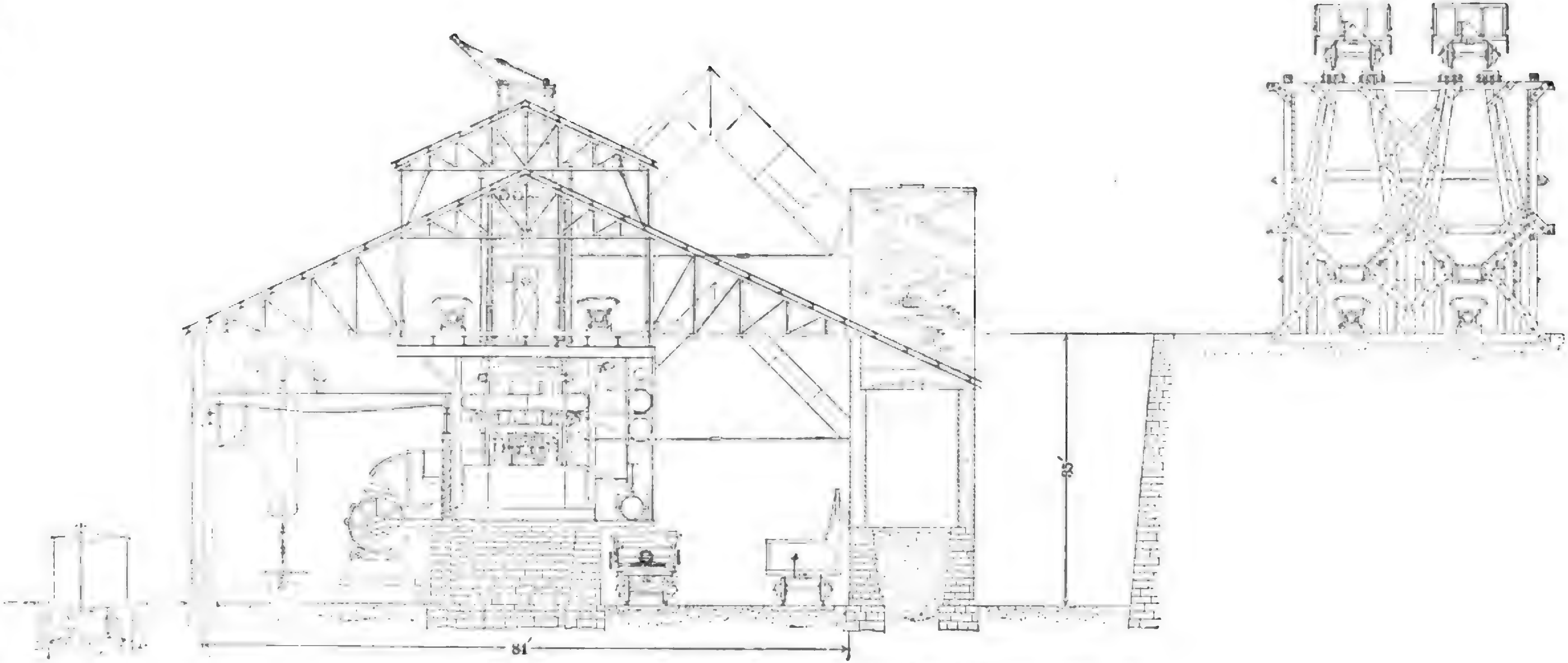
Roasting ore at main yard, Canadian Copper Co., at Copper Cliff, Ont.

Elsie Mine (Lake Superior Power Co.).

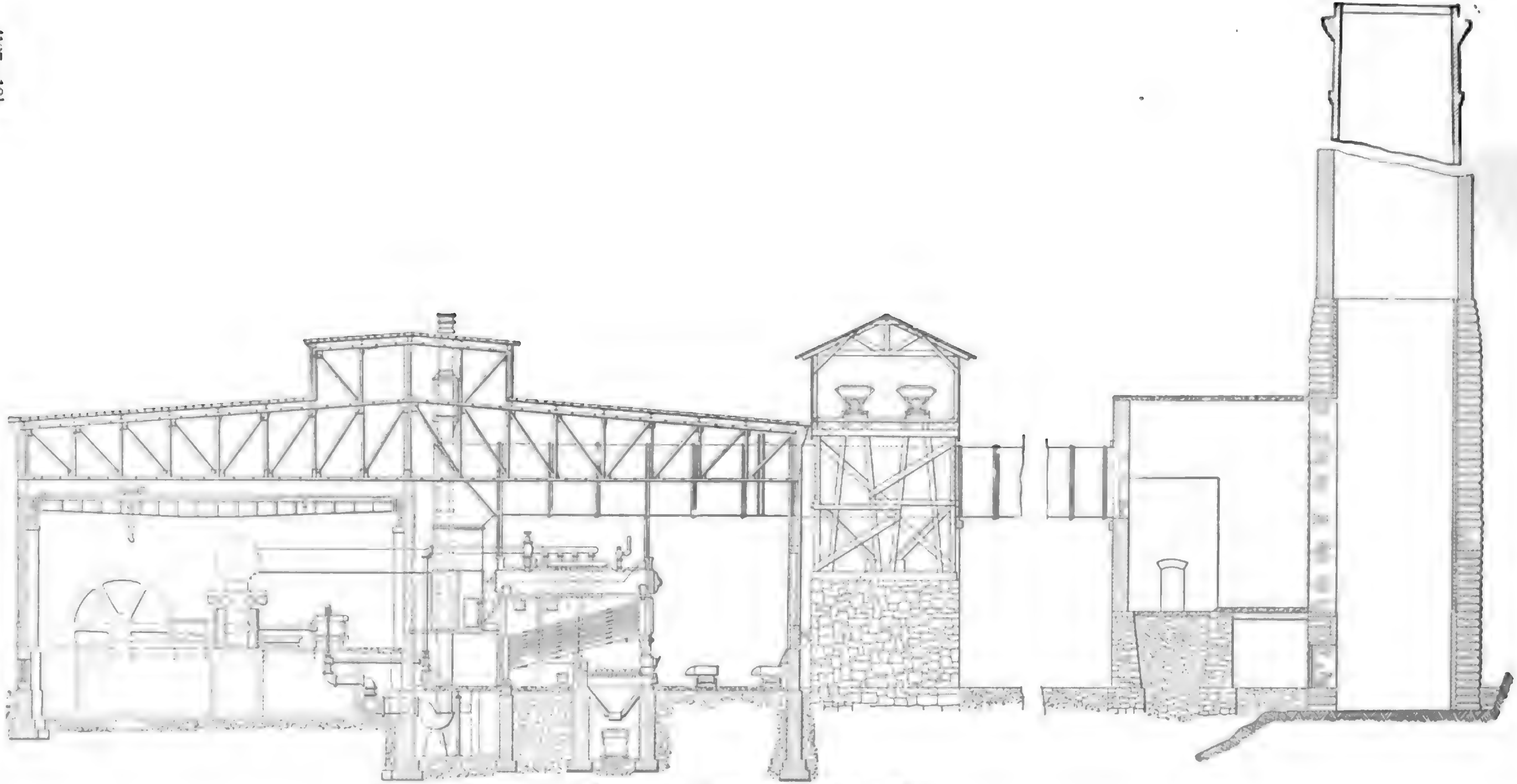
by Google



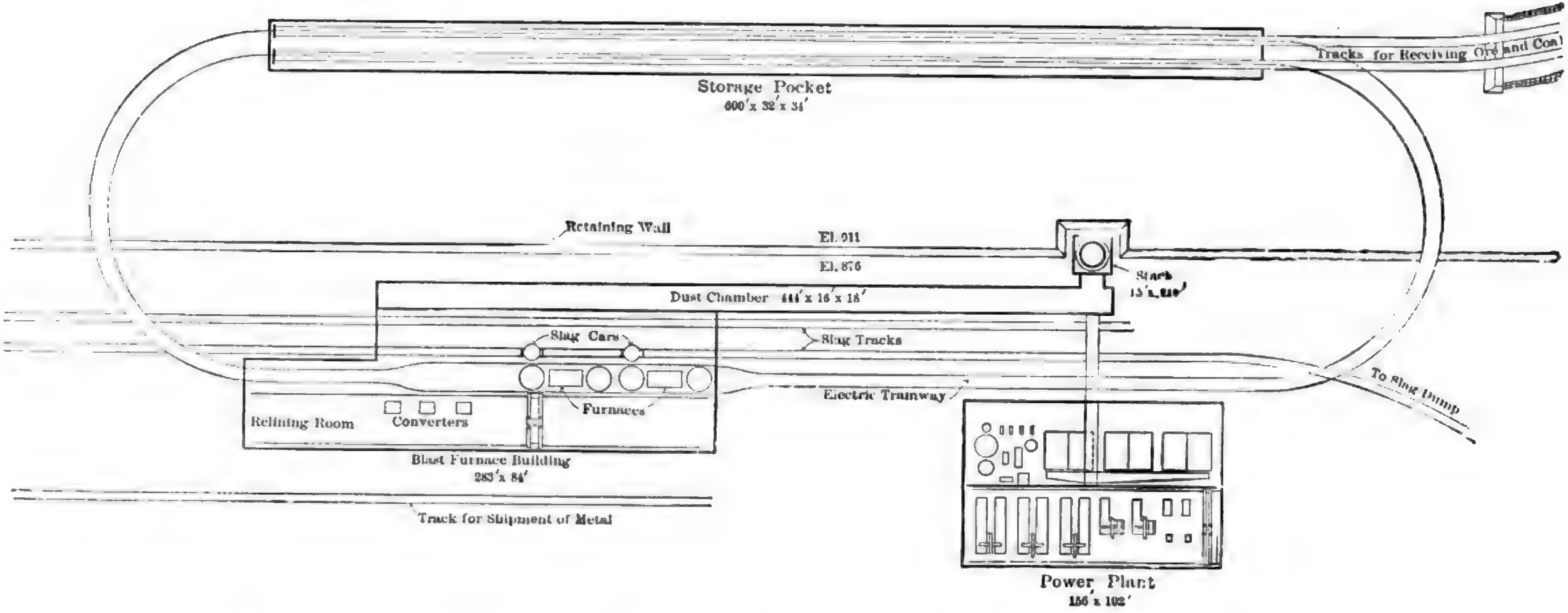
Interior of Smelter, Murray Mine, McKim Township.



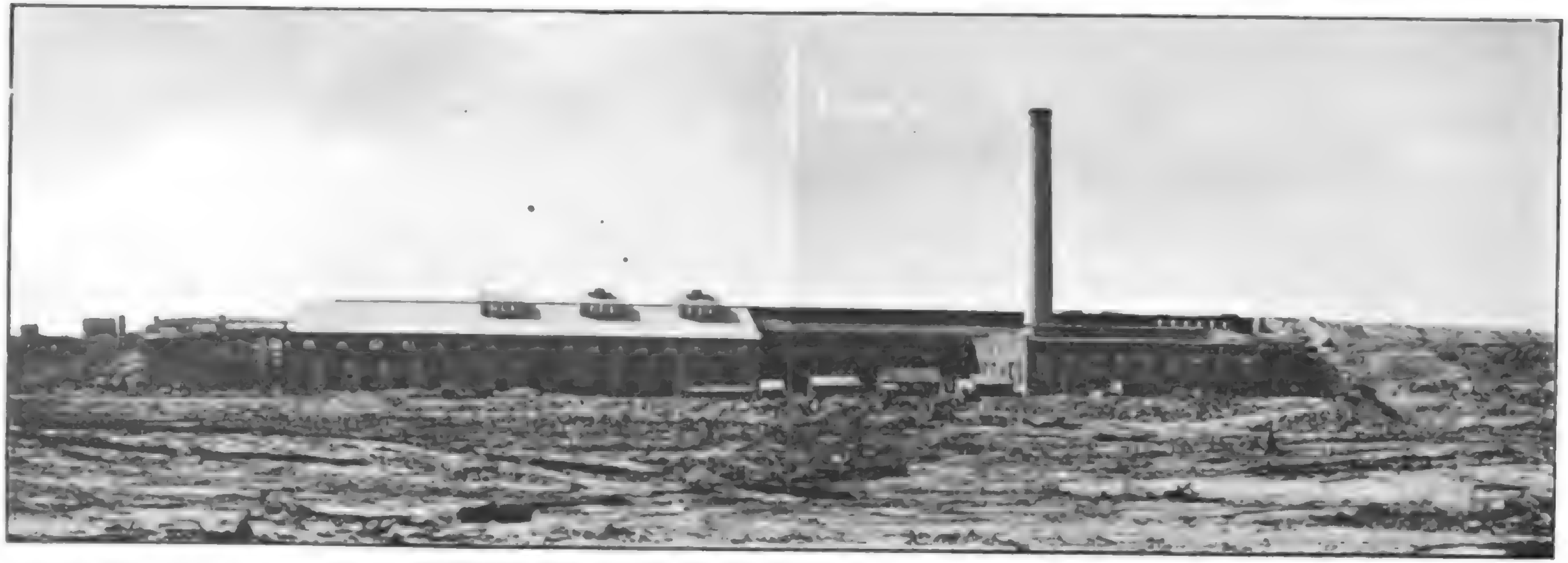
Cross Section of New Smelter of Canadian Copper Co., at Copper Cliff, Ont.



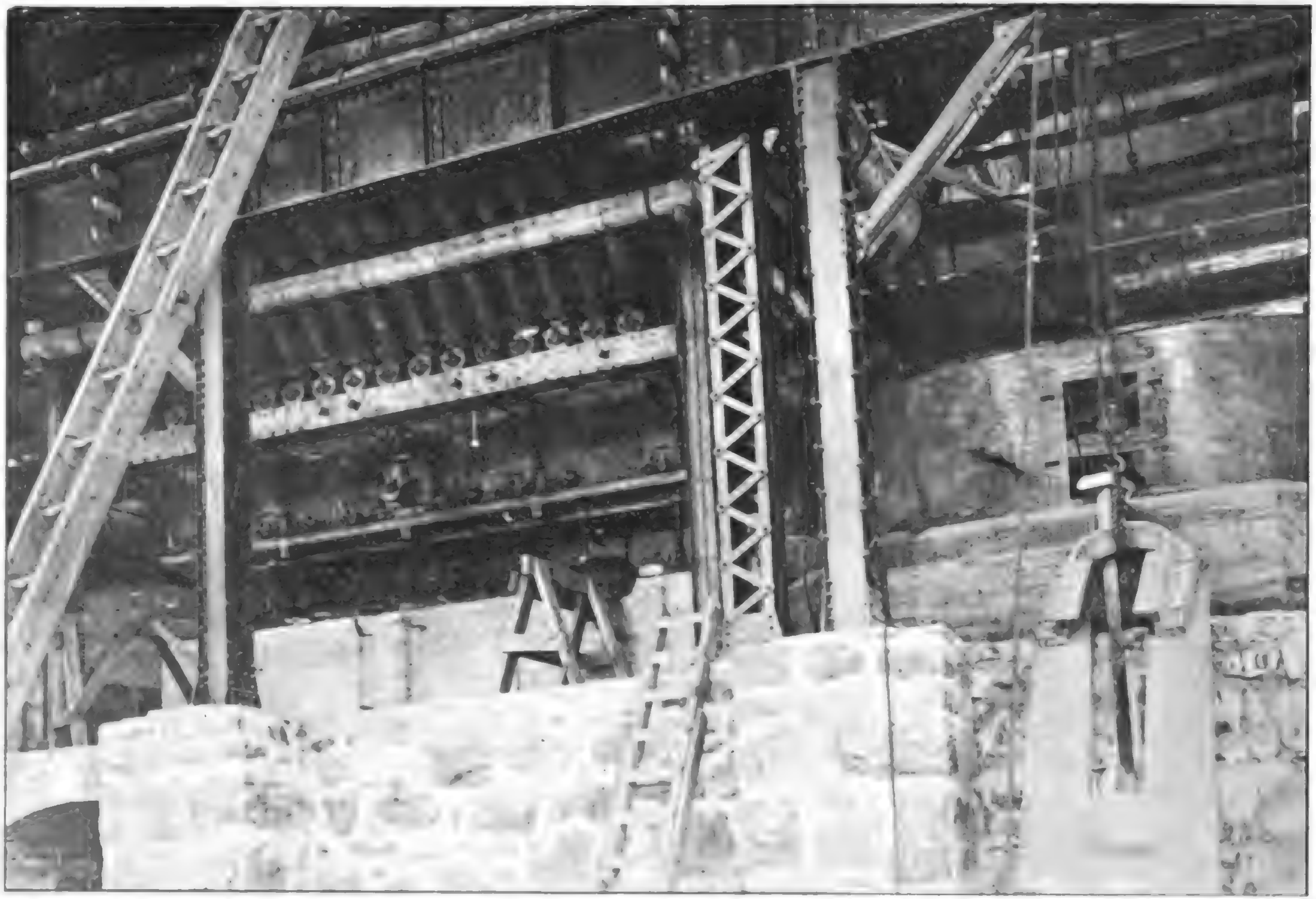
SECTION OF WORKS AT COPPER CLIFF.



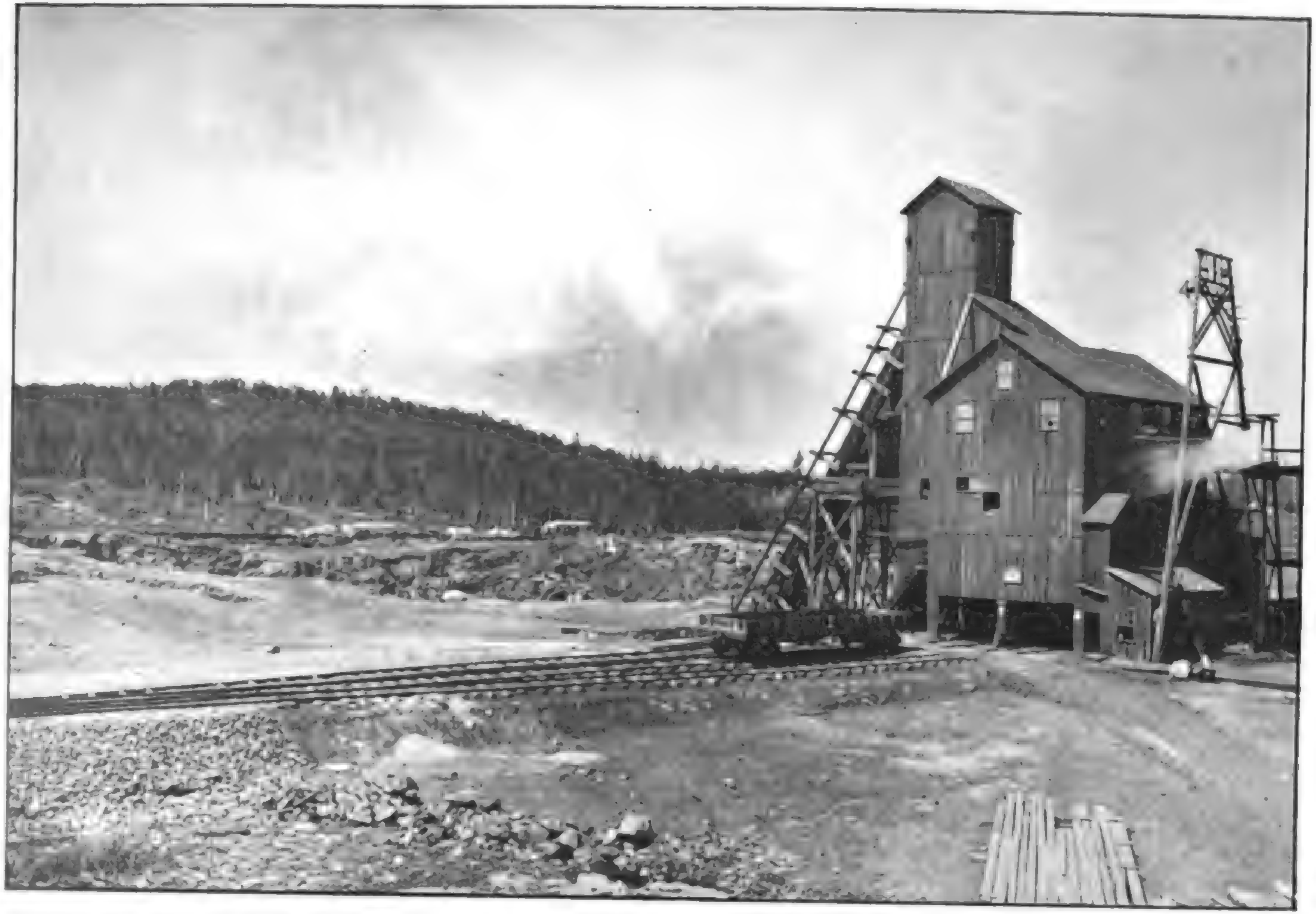
Ground Plan of the New Smelter and Works recently erected by the Canadian Copper Co., at Copper Cliff, Ont.



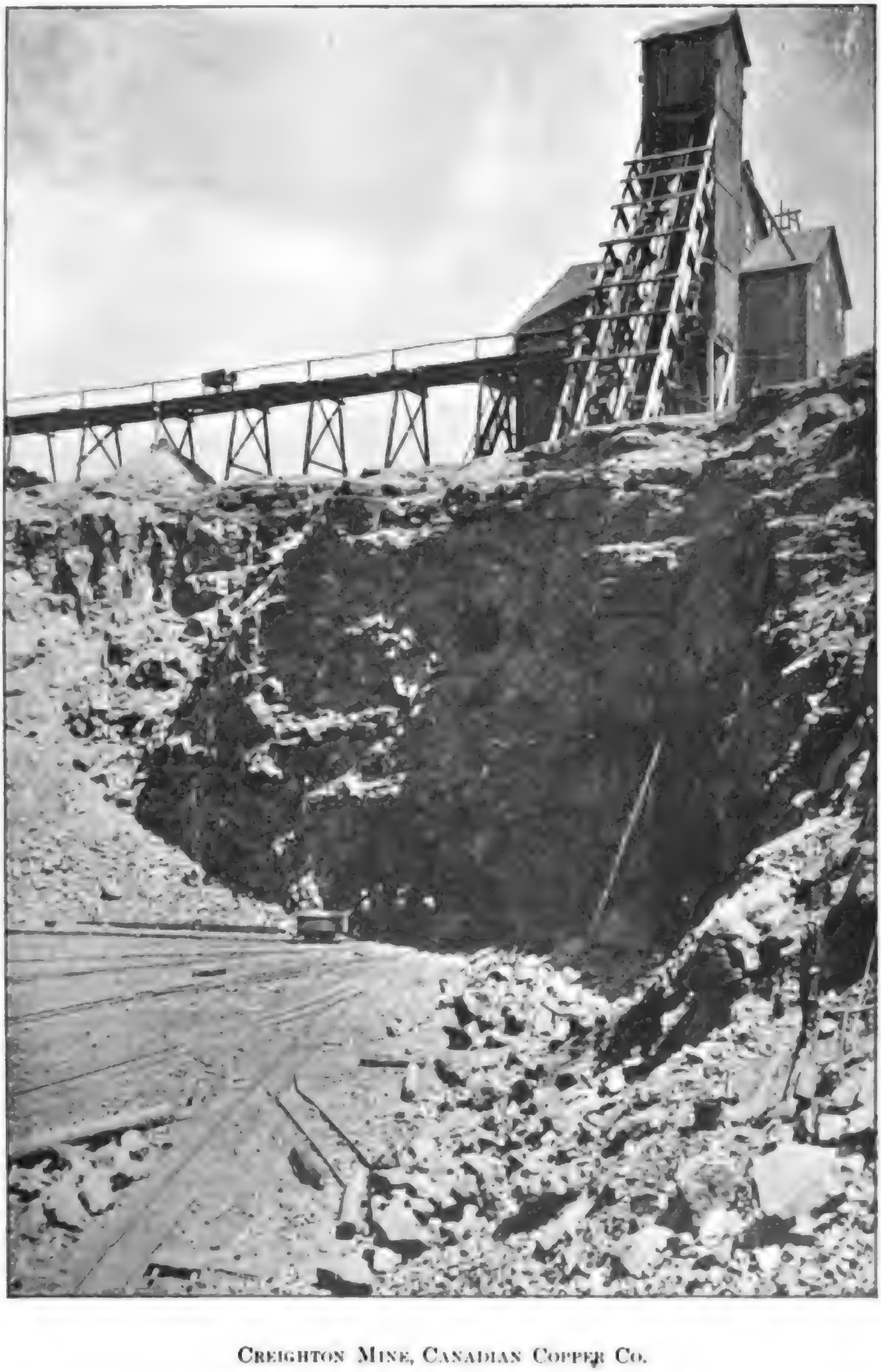
The New Smelter of the Canadian Copper Co., at Copper Cliff, Ont.
(Looking northwest.)



INTERIOR OF SMELTER IN COURSE OF CONSTRUCTION FOR THE CANADIAN COPPER CO.,
Showing the base of one of the new blast furnaces with forehearth partly completed.

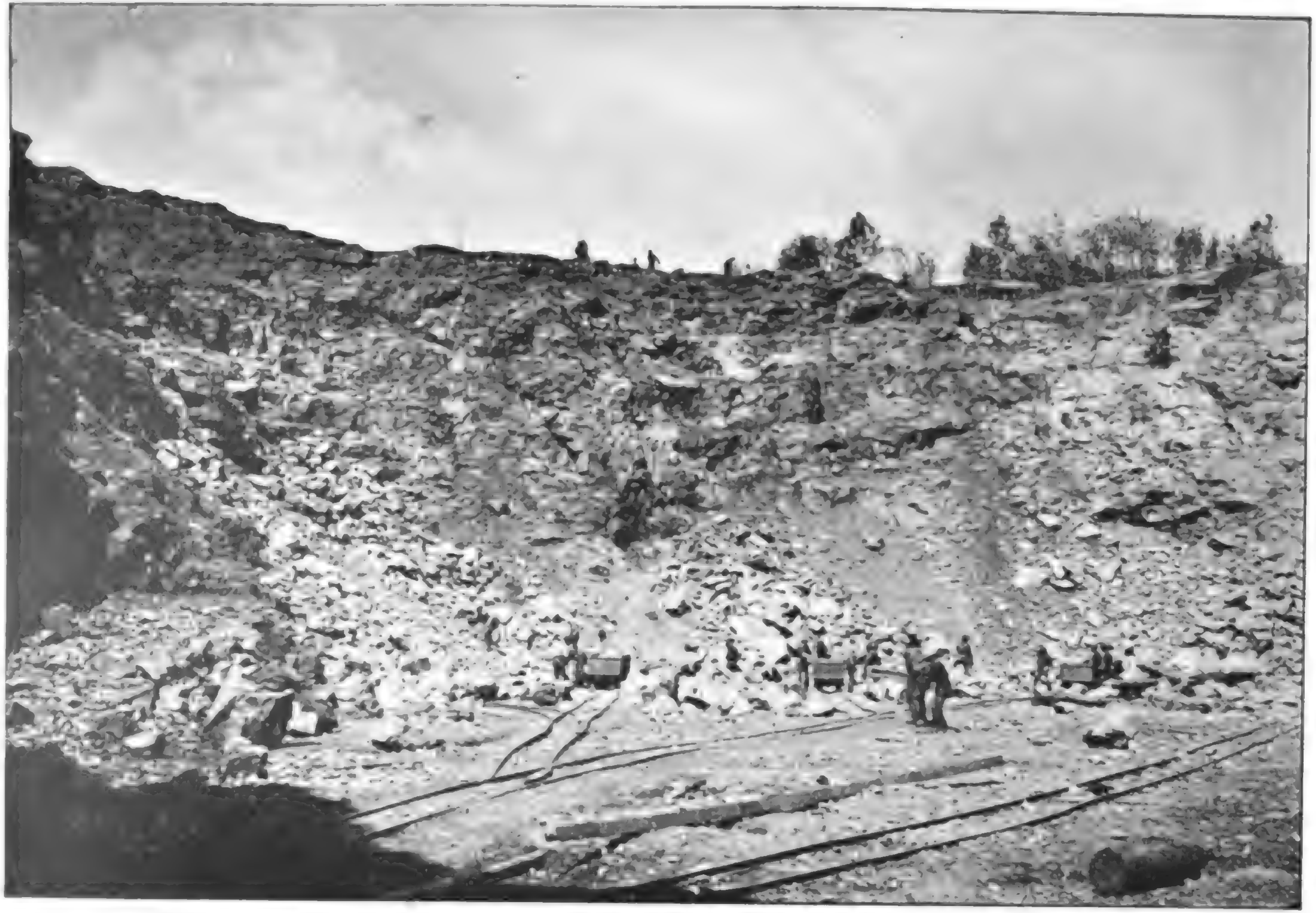


Rock House and main open pit Creighton mine.

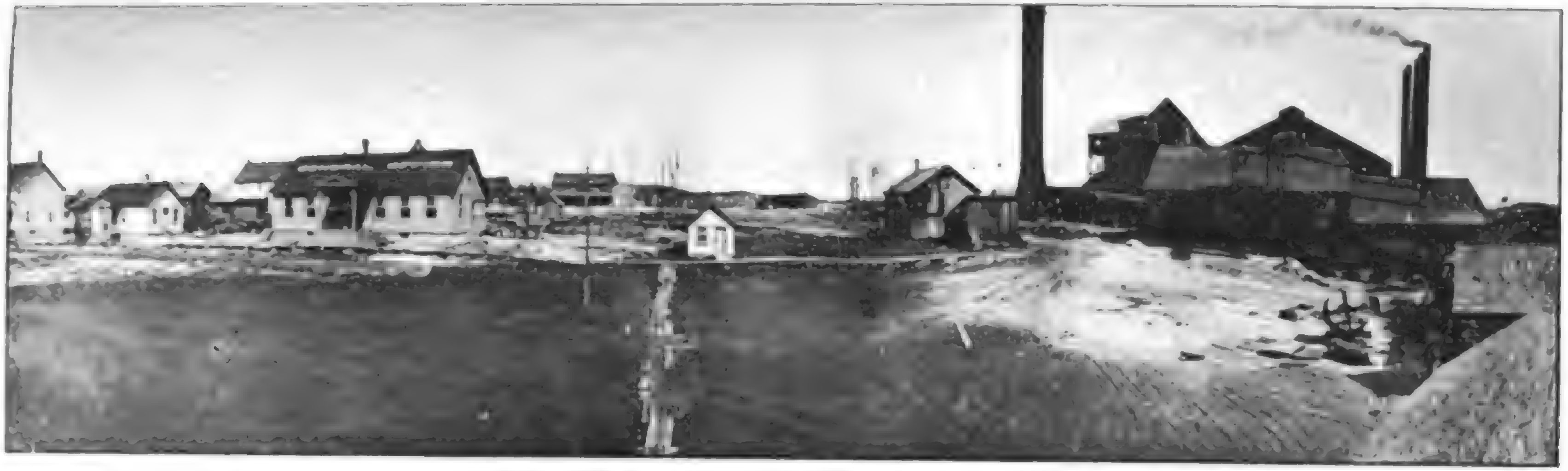


CREIGHTON MINE, CANADIAN COPPER CO.

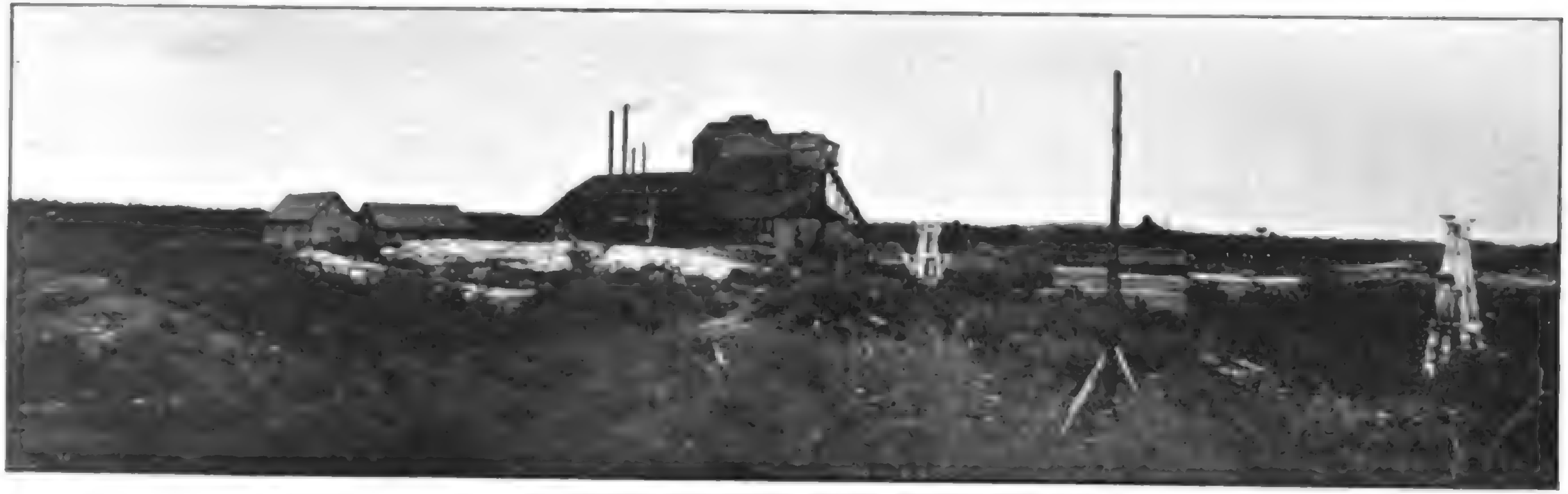
This view was taken from the side of the main pit looking S.S. E. and shows the methods of handling the ore.



Main Pit of the Creighton Mine, Canadian Copper Co.
This illustrates methods of mining and the removal of the ore.



The General Offices and Smelter of the Mond Nickel Company, near Victoria Mines Station.



Rock house over main shaft at Victoria Mines, Mond Nickel Co.

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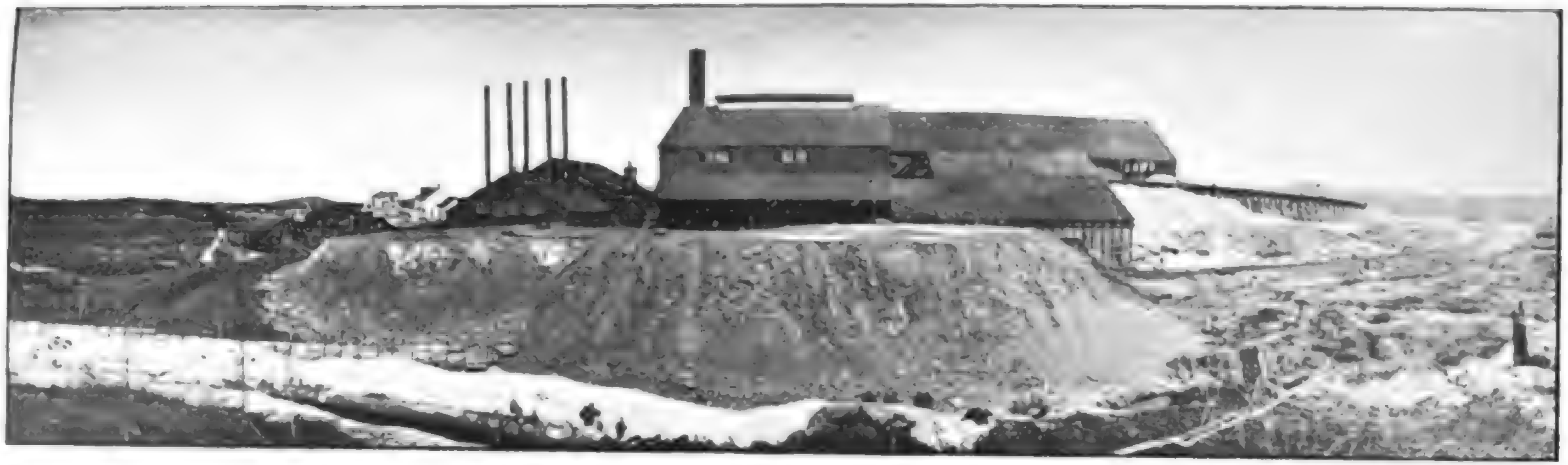
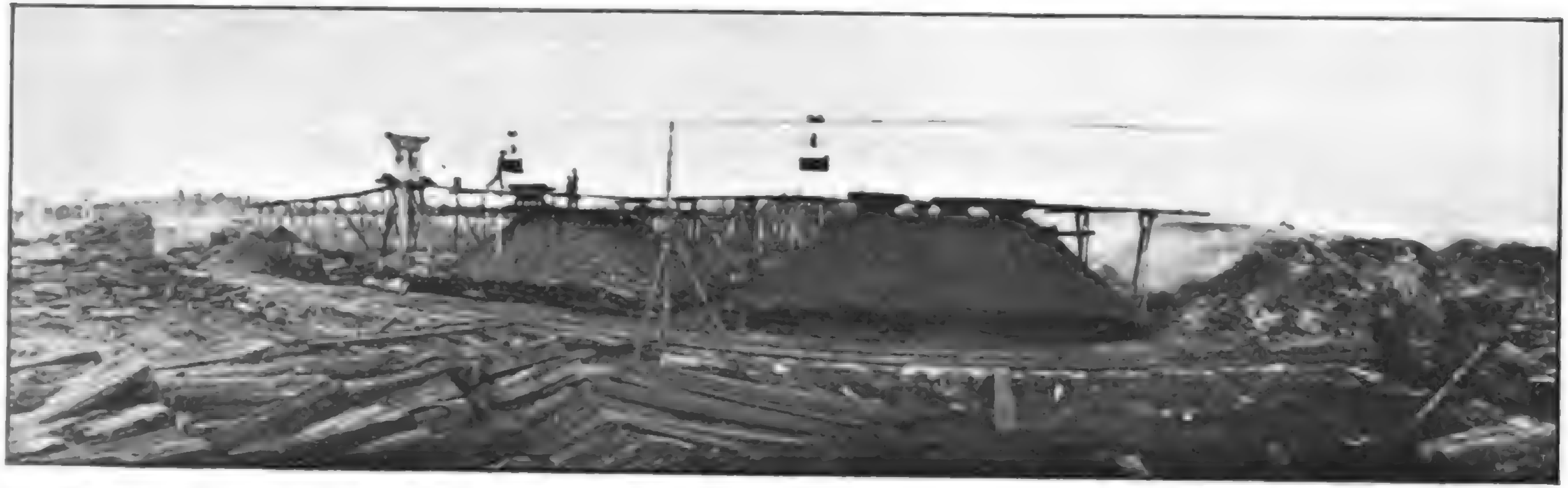
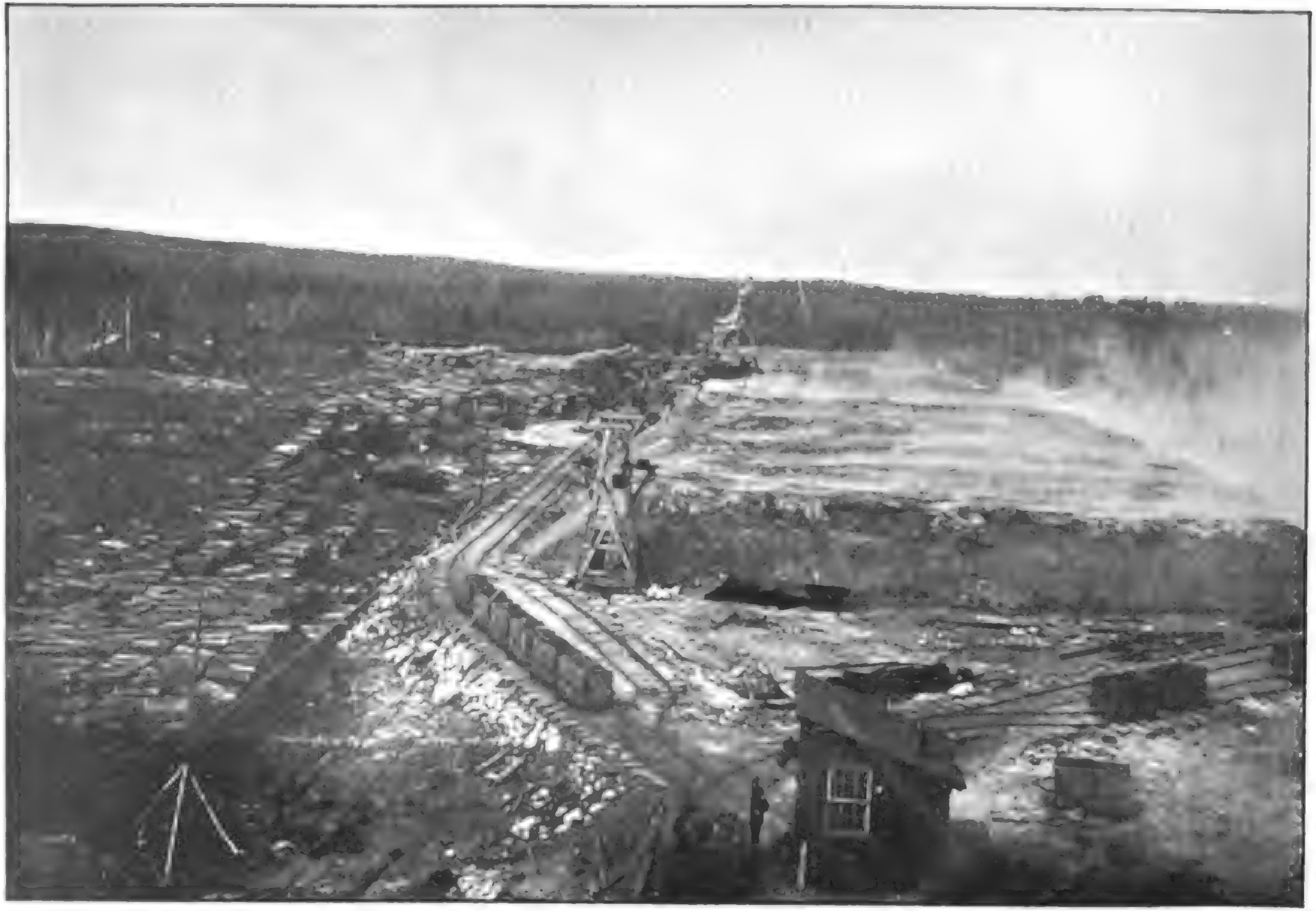


THE SMELTER OF THE MOND NICKEL CO., AT VICTORIA MINES.
Slag dump in the foreground.



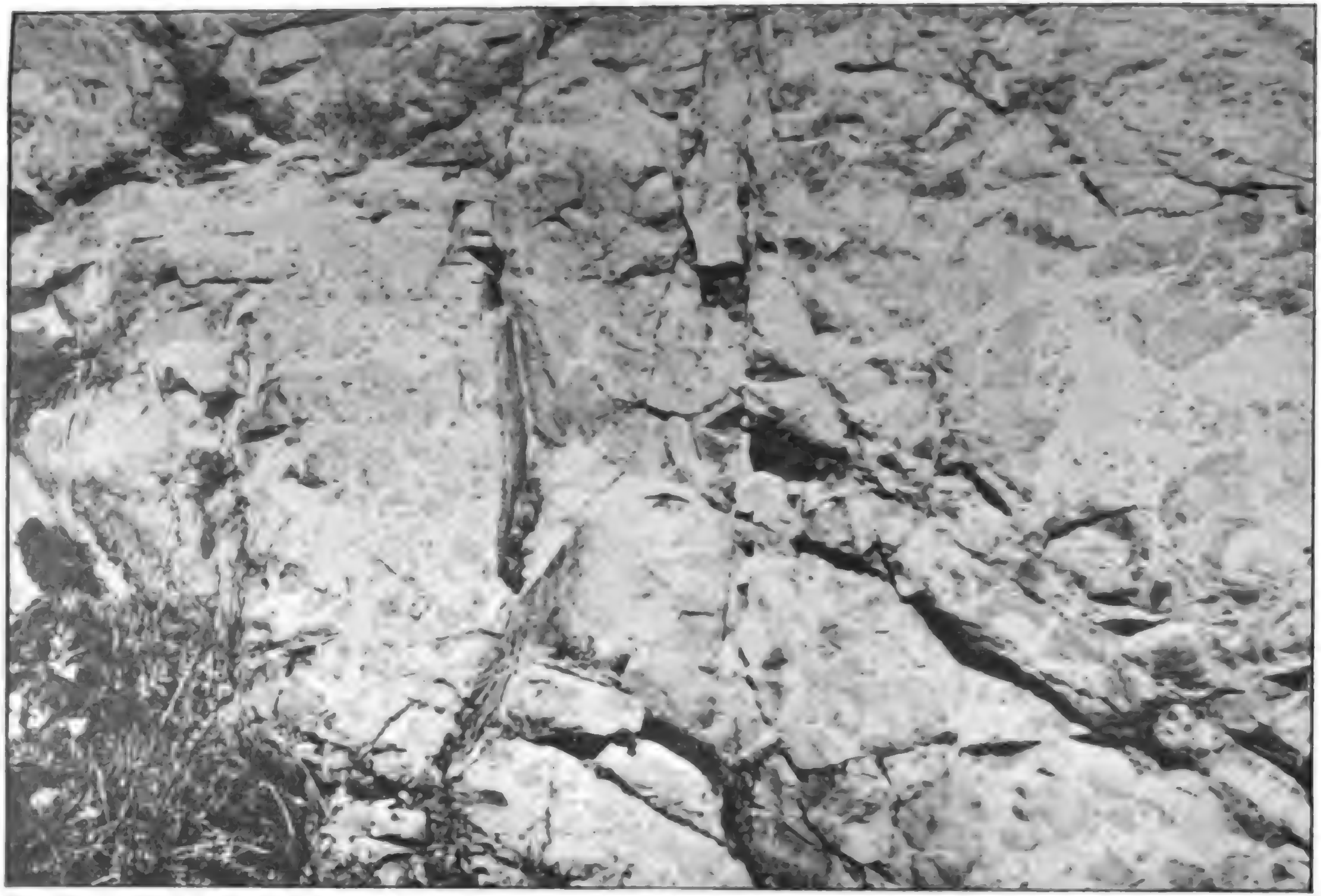
ROAST YARD AT VICTORIA MINES, MOND NICKEL CO, SHOWING METHOD OF CONSTRUCTION OF ROAST HEAPS.

d by Google

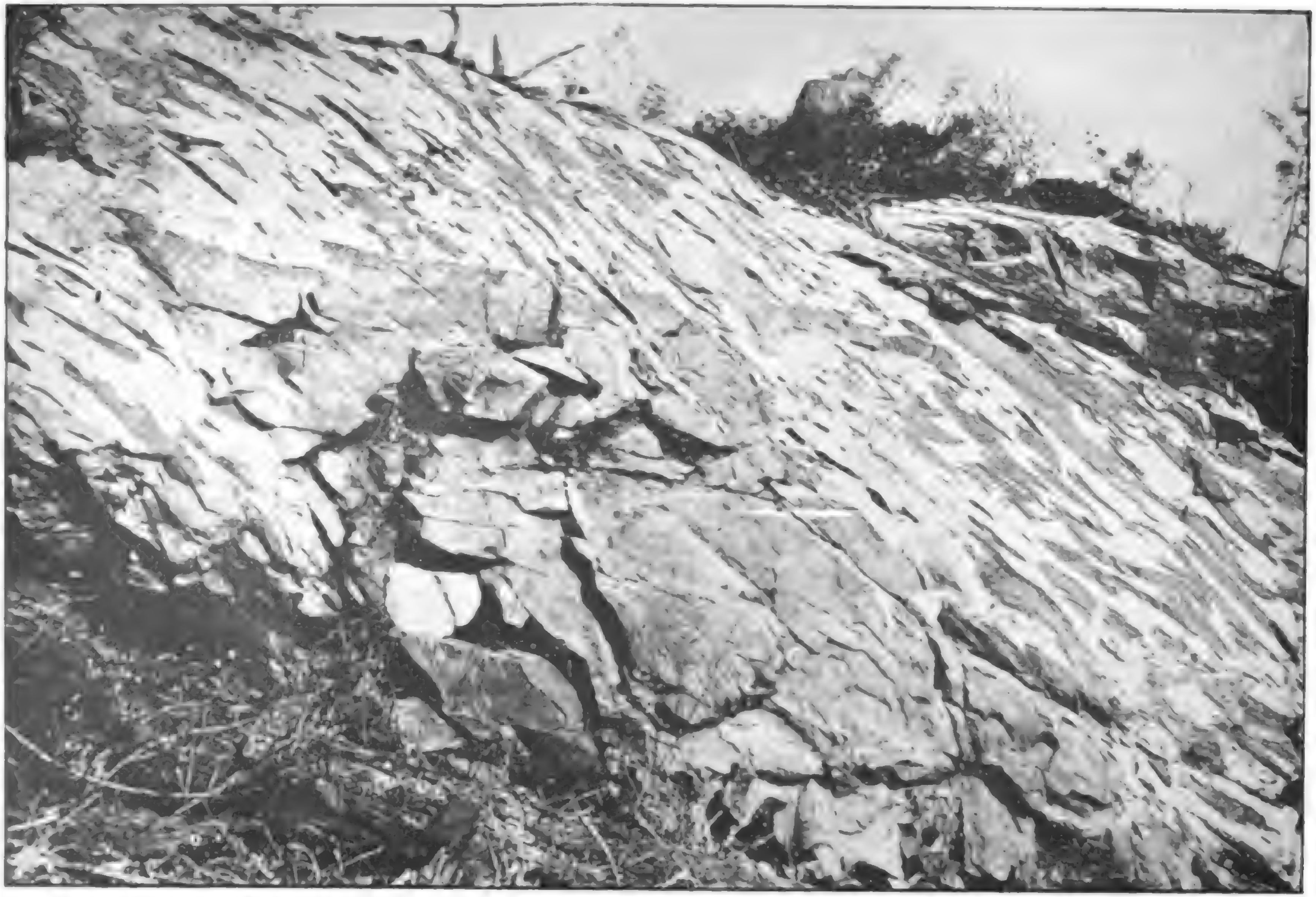


Roast Yard near Victoria Mines, Mond Nickel Co.

In the foreground is the weigh house while in the distance can be seen the rock house over the main shaft.



BRECCIA OF GRANITE AND HORNBLENDE SCHIST, OPPOSITE MANAGER'S HOUSE, MURRAY MINE.



BRECCIA OF GRANITE AND HORNBLENDE SCHIST.
One quarter of a mile E. of Murray Mine, north of Canadian Pacific Railway.

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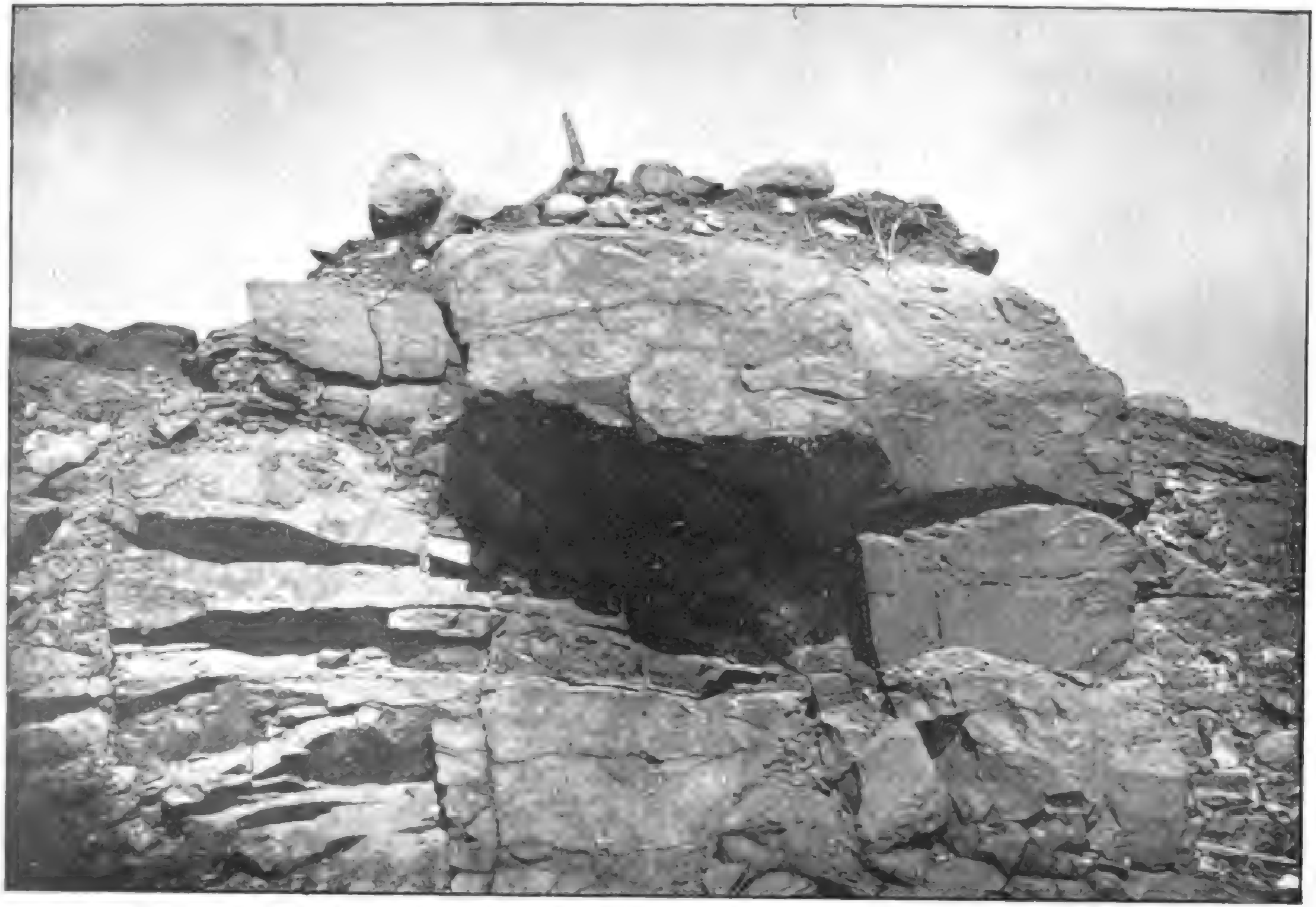
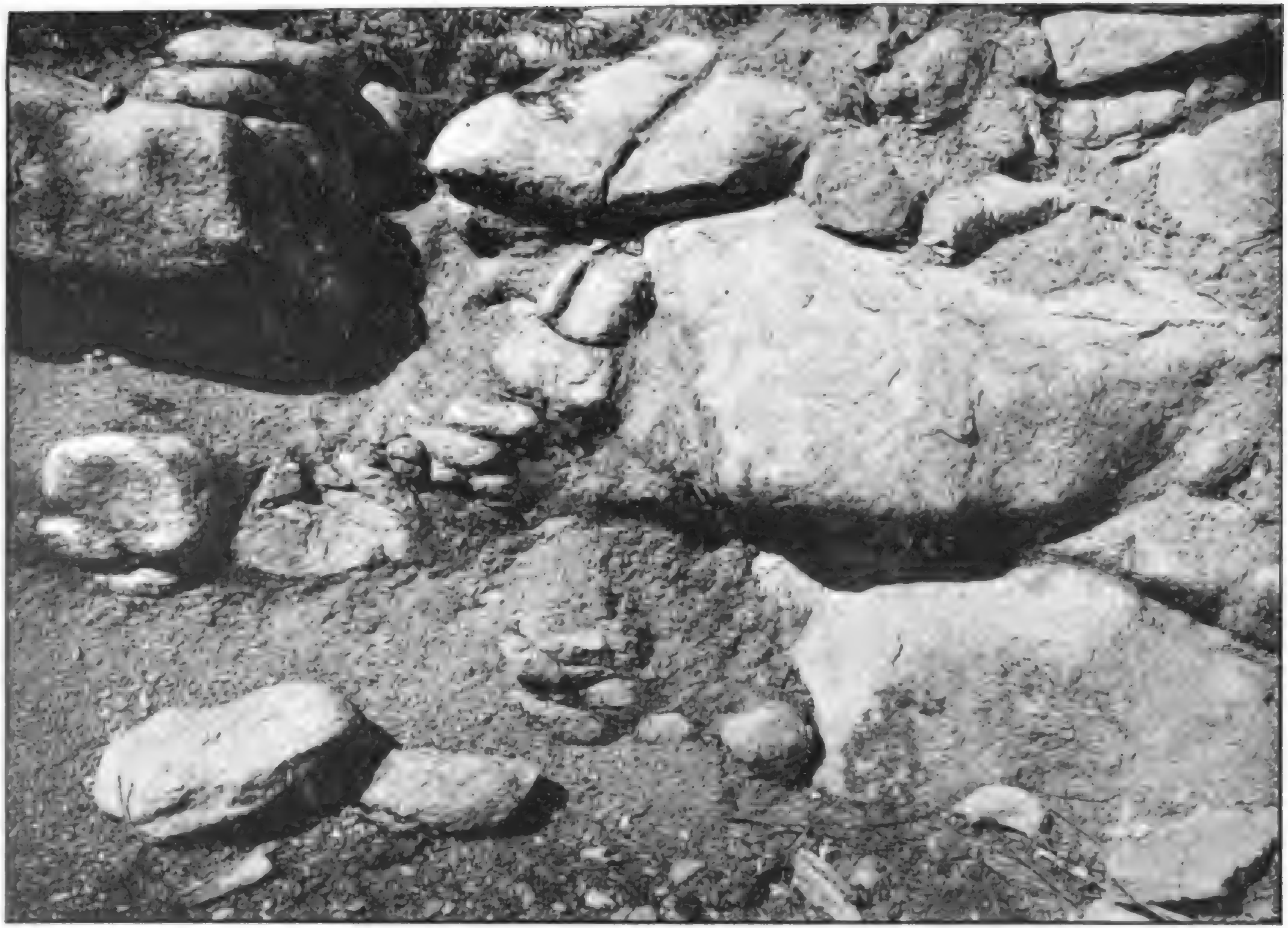
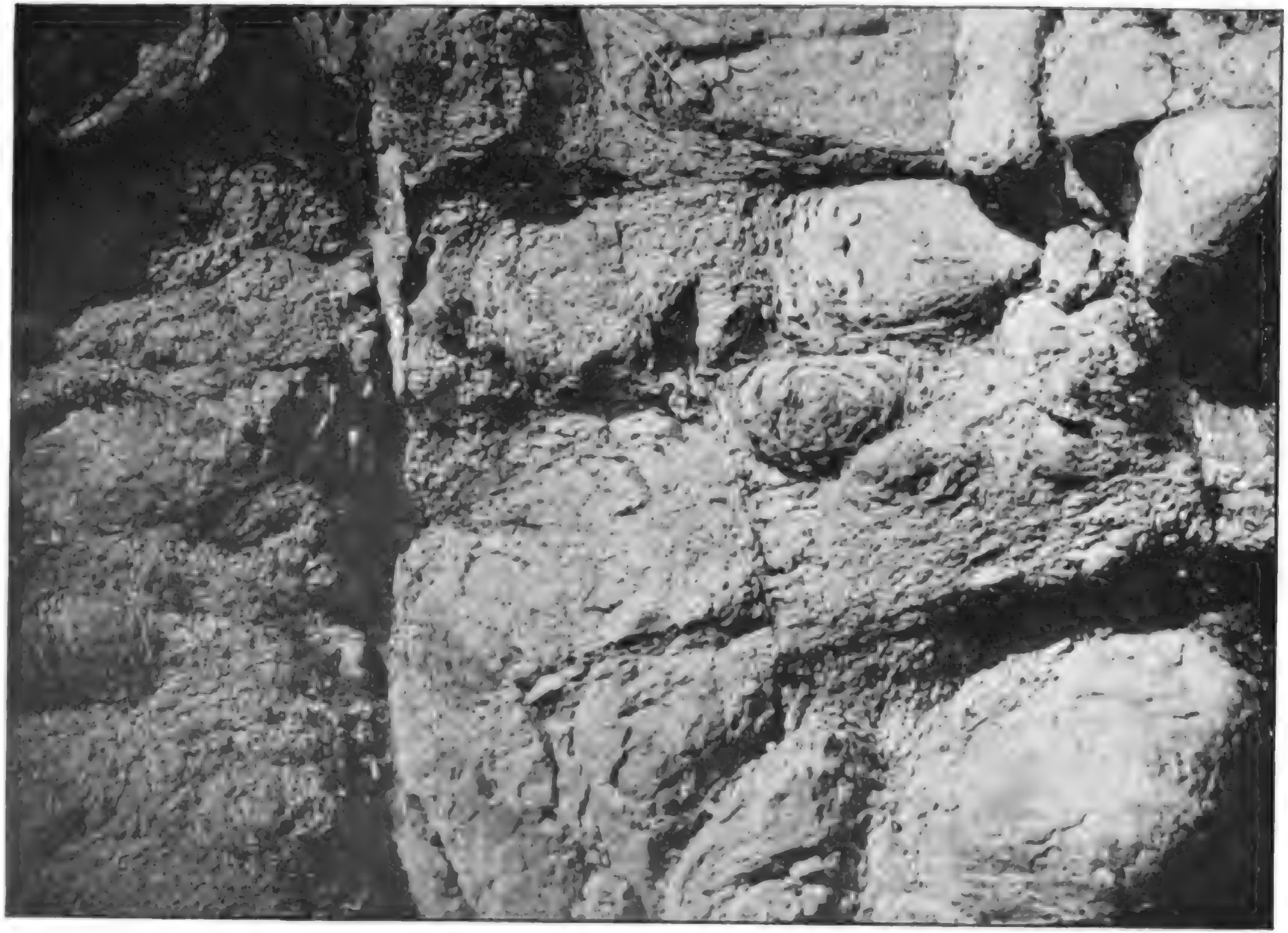


Dike of olivine-diabase cutting ore body at Murray Mine.

Showing basaltic or columnar structure.



PORTION OF DIKE OF OLIVINE DIABASE.
Showing boulder-like masses due to spheroidal weathering and disintegration.



Portion of Dike of Olivine-diabase.

The concretionary structure and spheroidal watering shown are characteristic of this rock.

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Report of the Commission appointed to investigate the different electro-thermic processes for the smelting of iron ores and the making of steel in operation in Europe. (Only a few copies of this report are available.) By Eugene Haanel. 1904.
Final report on the experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process. Eugene Haanel. 1907.

Preliminary report on the Limestones and the Lime Industry of Manitoba. J. W. Wells. 1905.

Preliminary report on the raw materials, manufacture and uses of Hydraulic Cements in Manitoba. J. W. Wells. 1905.

Preliminary report on the industrial value of the Clays and Shales of Manitoba. (Only a few copies available.) J. W. Wells. 1905.

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Report of the Commission appointed to investigate the Zinc Resources of British Columbia and the conditions affecting their exploitation. W. R. Ingalls. 1905.

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REPORT

ON THE

LANDSLIDE AT NOTRE-DAME DE LA SALETTE

LIÈVRE RIVER, QUEBEC

BY

R. W. ELLS, LL.D

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
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1908

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REPORT

ON THE

LANDSLIDE AT NOTRE-DAME DE LA SALETTE

LIÈVRE RIVER, QUEBEC

BY

R. W. ELLS

This landslide, which occurred on the morning of Sunday, April 6, 1908, was, as compared in area with several others which have happened in the province of Quebec, of somewhat small dimensions, but as regards the attendant loss of life is the most disastrous on record in eastern Canada.

The locality affected is the eastern portion of lots 1 and 2 of the river range of Portland west, about six miles north of the Little Rapid lock on the Lièvre river, now known as Poupore; near which place, in October, 1903, another somewhat extensive slide occurred: which was described and mapped in the Summary Report of that year, by the present writer.

The Salette slide is comparatively narrow, beginning on the bank of the stream, at the mouth of a small creek which flows in from the west at about 166 yards south of the end of the road at Chalifoux landing. The south end of the affected area is at, or near the line of division between lot 1 of range VI, and lot 6 of range V, on the south—owned by Camille Lapointe. The break occurred between his house—which was engulfed in the slide—and his barns; the latter remaining untouched. The length of the slide between these points along the bank of the stream is about twenty chains, or say 1,350 feet. The line of the break is irregular, extending inland at the widest part about 400 feet, as nearly as can be now estimated, and the area involved in the slide is apparently not far from six acres. The height of the clay bank which slipped into the river was about sixty feet above the present level of the stream.

The Lièvre river has been subject to land slides for a long period of time. The clay deposits line the stream for the greater part of the distance from Buckingham village, nearly to High falls—about twenty-four miles inland; except where interrupted by occasional bluffs of granite, gneiss or limestone of the Laurentian formations.

The presence of ancient slides can be recognized readily by the usually hummocky or irregular nature of the surfaces where these have taken place, but in many cases they have been under cultivation for years, while others are covered with a growth of timber. These clay areas are bounded at a short distance, on either hand, by hills of the old rocks, often steep on the sides facing the river valley, some of which show smooth glaciated faces, caused by the passage of the glacial ice. This ice evidently followed the course of the old river channel, which must have been excavated in very early geological times.

Some of these rocky bluffs border on the river, in which cases, the portions of the shore opposite are occupied by clay deposits. Where these deposits have been undisturbed, the clay is usually homogeneous in character, bluish in colour, tough and plastic when subjected to the action of water; occurring in heavy beds, nearly horizontal in position, and with thin layers of arenaceous silt, which separate the heavy layers or strata. When saturated with percolating waters, the silty layers suddenly pass into a semi-liquid condition.

In places where former slides have occurred, the clays having been broken up, are mixed with silty material and the original surface soil; and large sheets of the clay occur with steep inclinations, some in the direction of the river.

In these recomposed deposits, the remains of forest trees—buried at the period of the original slide, can occasionally be seen projecting from the broken down face of a more recent slide.

The last of the previously recorded land slides on this river occurred on Sunday, October 11, 1903, a short distance below the lock on the canal at Poupore post office—formerly Little rapids. This was described in the Summary Report for that year. It involved an area of about ninety-five acres, extending from the foot of the mountain on the west side of the river, nearly half a mile inland, at this place, and displaced the surface to a depth of about twenty feet, to the bank of the stream. The direction of the movement was clearly northeast from the base of the mountain, but the overflow of the clay which filled the channel for about three-fourths of a mile below the lock, also occupied a considerable area on the east bank directly south of the lock. A part of this overflow was forced northward, and filled the lock itself. The river was dammed by the clay to such an extent that the back water on the stream extended to within a short distance of the High falls. The slide occurred in an area occupied by previously undisturbed clays.

This slide at Poupore was evidently caused by several days' heavy rains, by which the whole of the broad clay flat was saturated, forming a very heavy overburden upon the underlying body of clay and silt partings. At the junction of the clays with the rock of the mountain at the back, a layer of small broken rock occurred, and the rainwater descending the slopes of the hill, evidently passed downward along the line of contact, to a layer of silt at a depth of fifteen to twenty feet from the surface. This layer having reached the point of saturation, passed into the semi-liquid condition, and, with a very gradual slope to the river, the pressure of the overlying mass of clay finally reached the stage when the equilibrium of the clay mass was overcome, and the upper stratum moved forward in the direction of least resistance: which was the bank of the river. The amount of displacement measured at several points on the flat itself, seemed, as could be seen by the displaced road which traversed the area, to be about 300 feet as a maximum. The movement was not along the smooth glaciated surface of the underlying rocks, but merely along the silt planes in the clay itself.

The disaster at Salette, or Chalifoux landing, differs somewhat in character from that which occurred in 1903 at Poupore. While the original cause of the Salette clay slide may be similar to that at Poupore, namely, a descent from the hills at the back, or to the west of the village, in the recent case, the crack occurred in the surface of the soil at about 200 to 300 feet from the front on the river. The actual cause of the slide appears to have been a fissure, into which the water descended until it reached an underlying portion or stratum of blue clay which, along the edge of the break, had an exposed dip towards the river of 18 to 20 degrees—when the overlying burden of clay, silt and sand overcame the resistance and slipped forward into the river bed. The momentum of this sliding mass, starting from an elevation of sixty feet, and at such a short distance from the front of the bluff, must have been very considerable and the movement correspondingly rapid. The ice in the river was apparently unbroken at the time, and was lifted and carried forward over the east bank on which Salette village was located, at an elevation of not more than twelve to fifteen feet above the present level of the river, and which was some feet above the ordinary summer level. The rush of the ice came with such force against the village as to completely demolish the greater portion. In fact, everything within its course was destroyed: including twelve houses and some twenty-five outbuildings, which were entirely destroyed to their very foundations; while on the margin of the ice movement several other buildings were more or less damaged. On the west bank where the slide started, three houses were entirely destroyed, together with several outbuildings. The total loss of life as far as can be ascertained, was thirty-three persons.

The rush of ice was followed by a rush of water from the river, which carried portions of the ruined buildings and the bodies of villagers inland beyond the road which is parallel to the shore; depositing the débris at an elevation of about fifty feet above the river level. The receding wave swept backward over the village site with sufficient force to remove the greater part of the ice above, as well as the greater portion of the débris of the village itself; though scattered ice-blocks could be found several days after the disaster. All this débris was swept down the river, together with a number of bodies, which had probably been entangled in the ruins, and carried away in the same movement:

proved by the finding of several corpses as far down as Buckingham village. Of the number of persons who lost their lives in this distressing calamity, not more than half could be accounted for. Of the missing, some have probably been buried in the roughly piled masses of clay or mud along the river bed, with which the channel was choked; while others have been swept down stream, and may be engulfed in the numerous eddies along the river.

The great loss of life in Salette village was, without doubt, caused in large part by falling timbers; the bodies in many cases being badly crushed and disfigured. Had the ice not been present, doubtless the rush of the water would have damaged and possibly destroyed some of the smaller buildings nearer the water; but would not have wrought such wholesale destruction, and probably would have left a larger amount of the clay upon the east bank, much of which must have been kept in check by the overlying ice-mass. The width of the channel at this place, as measured in the survey of the district some years ago, is between 250 and 300 feet. The residents in the houses engulfed on the west side were probably caught in the sliding clays and silts. Several persons were rescued when nearly lifeless from smothering, and exposure to the icy waters.

The unstable nature of the material composing the bluff which fell, can be seen in the close admixture of blue clay and sandy silts in the beds deposited. On the second day after the disaster, portions of the bank were still falling in considerable amount: the upper portion breaking off in masses sufficient to move forward over the debris to a distance of 100 to 150 feet, until stopped by the rough surface of that already fallen. At the time of our visit, it was practically impossible—owing to the unstable condition of the edge of the break—to approach near enough to make an accurate survey of the locality.

The damage on the east side opposite Chalifoux landing, and thence to the road at the old North Star landing, was apparently caused by the water backed up by the clay dam, by which the water in this direction rose to a height of eight to ten feet. Several small bridges were washed away on the little creeks, but the damage to buildings was slight. Above the old landing, apparently no damage was inflicted.

As much interest is now being taken in the phenomena of these landslips, it is considered advisable to refer to other instances of this kind which have occurred in the province of Quebec within comparatively recent times, as illustrating the conditions by which these were brought about. The following extracts taken from a report of the late Dr. Chalmers—of the Geological Survey—on these occurrences along the St. Lawrence, between Three Rivers and Quebec, are, therefore, added:—

"Three landslips of considerable magnitude have been known to occur in this part of the St. Lawrence valley within the last sixty years, and evidences of others, of which there is no account, were observed. The first of these referred to, took place on the bank of Maskinongé river, about nine miles to the south of the granite hills, on April 4, 1840, and was examined and described by Sir W. E. Logan. The area affected was about eighty-four acres, and the chasm is described as oblong in shape, with a narrow funnel-like end towards the river. The total length was about 1,300 yards, while the breadth varied, the widest part equalling 600 yards. When examined by Sir W. E. Logan, the bottom of the widest part of the pit was found to be thirty feet below the level of the surrounding country. The material transported into the valley of the Maskinongé river filled it to a depth of seventy-five feet for a mile and a half. The cause of this landslip, Logan believed to be pressure on an inclined plane, assisted by water, although no subjacent rock-surface was seen.

"The St. Albans landslip occurred on April 27, 1894, on the west bank of the Ste. Anne de la Pérade, about four miles above the village of St. Albans, or seven miles from the Rivière Blanche landslip. Here the deposits (Leda clay and Saxicava sand) slid down bodily into the valley of the river for the space of three miles and a half. The landslip seems to have been in three parts, the first movement being at the northern end, where it was about ten feet deep. This was followed, after some hours, by another which took place immediately to the south of the last; and finally a third descended just below the second, leaving a pit 175 feet deep. The average depth of the whole chasm was not less than 100 feet below the general surface of the ground, and its width about a mile. The mass of material thrown into the valley of the Ste. Anne permanently changed the course of the river.

"The Rivière Blanche landslip was closely similar to that of Maskinongé river described by Logan. As stated above, it took place on the east bank of the Blanche, a tributary of Ste. Anne de la Pérade, at St. Thuribe, about three miles north of St. Casimer village. The banks of the latter river are low and the country flat, forming a part of the St. Lawrence plain, as far up as St. Thuribe, where the valley is crossed by a boulder clay ridge. The superficial formations consist of Saxicava sand and Leda clay, and boulder clay. In the pit where the landslip occurred, the Leda clay is prolific in marine shells, chiefly *Leda arctica* and *Macoma greenlandica*.

"The chasm remaining from this landslip is also irregularly oblong in shape, like that of the Maskinongé valley described by Logan, with a narrow opening at the end towards the Rivière Blanche. At this point the breaking down of the beds began, and through this opening the whole of the flowing material was discharged. The length of the pit, east and west, is about 1,050 yards, extreme width 600 yards, maximum depth about twenty-eight feet; total area, eighty-six acres. The descent of the bottom throughout its whole length is approximately twenty-seven feet or about ten inches to the hundred feet, and the gradient is comparatively uniform from the eastern end to the present bottom of the river.

"The movement of clay and sand on such a low gradient, it is obvious, could only have taken place when these materials were in a semi-liquid condition, and from all accounts the landslip resembled the bursting of a reservoir of water. Those who witnessed it, however, informed me that very little water was seen, the flowing mass consisting of a very soft clay or mud. Indications of a movement in the clays were first seen on the evening of May 6, in a small hollow in the bank down which a trickling stream ran, but no attention was paid to it. Up to the hour when the landslip actually commenced, the people who lived on the ground that was swept away crossed it by the highway and went in and out of their houses without any thought of the impending catastrophe. About five o'clock on the morning of May 7, the breaking away of the clay beds began where some slipping had been noticed on the previous evening. Very soon the movement seemed to gather force and work backward through the drier and harder clay in the immediate bank of the river, inside of which it expanded on both sides into the terrace. The softer material flowed out from beneath, while the upper and more coherent clay split off in vertical sheets and columns which were borne away in the sliding surging mass. This continued for upwards of three hours, when the transporting power seemed to have spent itself, and great masses of clay which had become detached from the walls of the chasm stranded in its bottom, and at the time of my examination were seen standing in various positions, some of them resembling cones, pyramids, etc.

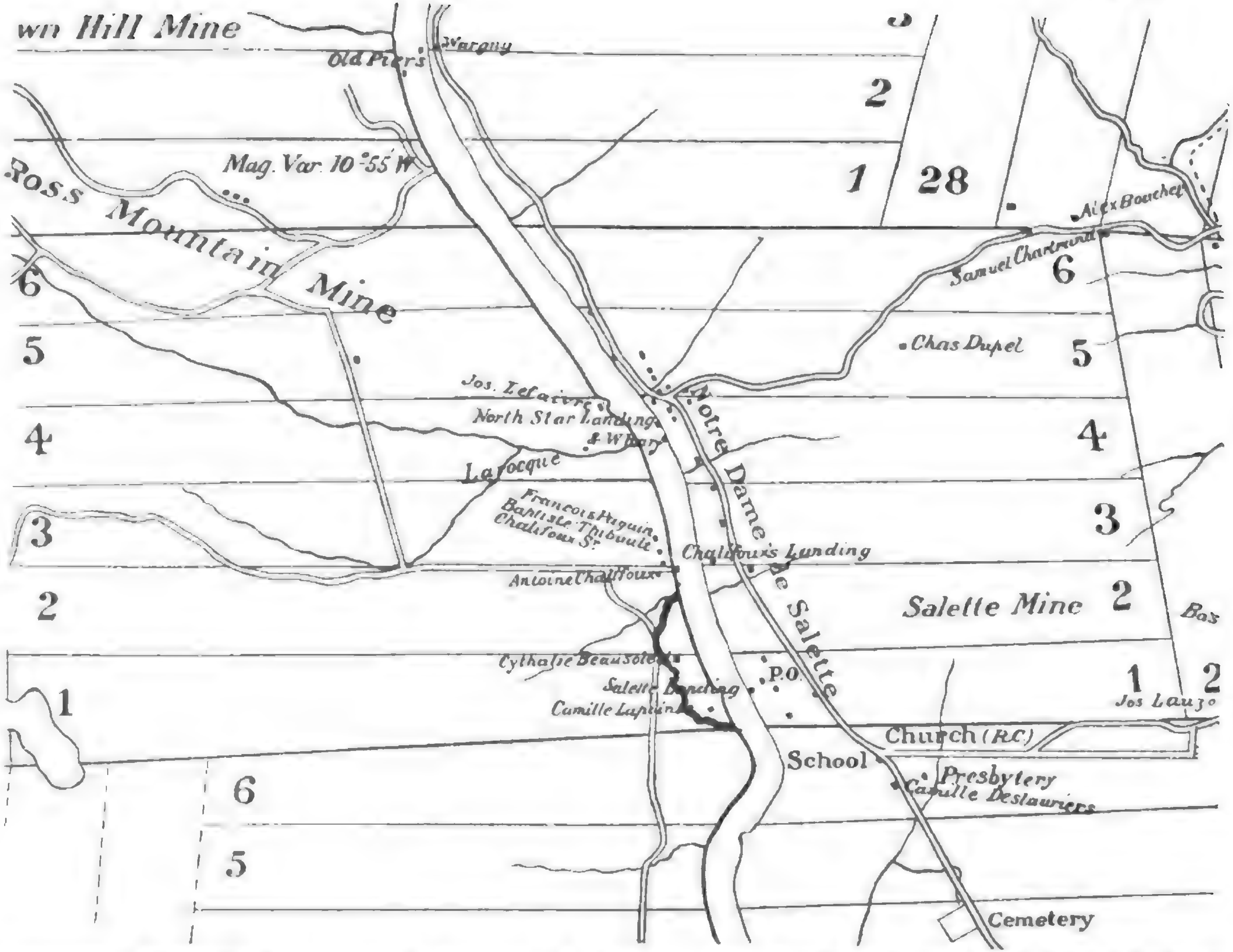
"The marine deposits in which this landslide occurred are quite arenaceous and silty, especially in the upper part, and no well defined break was seen to exist between the Saxicava sand and Leda clay, the one graduating into the other. Hence the surface waters percolate downwards to a considerable depth during the period of snow melting every season. This excess of water passing into the silty and arenaceous clays and sand must have given the beds greatly increased weight. It is probable also that a zone or layer of softened clay of some thickness was thus produced beneath the arenaceous strata, and held in by an impermeable hardpan below, and by the hardened clay-banks on the riverward side and on the north where a depression exists, supposed to be the seat of an ancient landslip.

"The cause of the Rivière Blanche and other landslips of this part of the St. Lawrence valley seems to be:—

"1. The silty and arenaceous character of the Leda clay, rendering it capable of absorbing and retaining a large amount of water; and,—

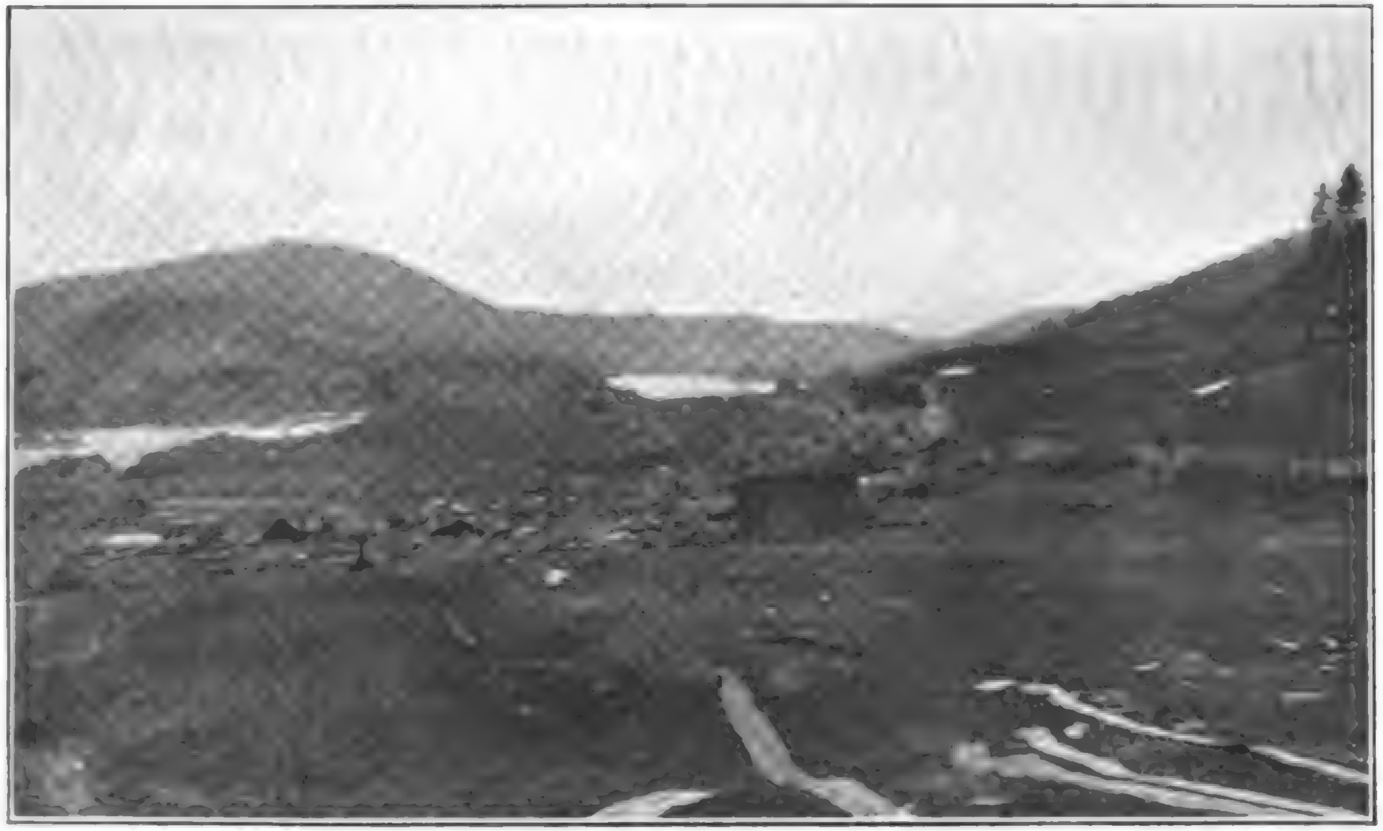
"2. The increased precipitation during the seasons when these landslips occurred, which saturated the deposits and gave them greater weight than usual. These conditions doubtless produced unstable equilibrium of the beds, resulting in displacement and a flow of the semi-liquid portion. The more coherent clays, breaking down as described, and mixing with the soft material, produced a tumultuous mass of mud, clay and sand, which descended into the nearest valley."

The extracts quoted above, appear to cover very thoroughly the principal points involved in the occurrence of landslips, at least in the province of Quebec. It would appear also, that a recurrence of similar conditions will at times be attended with similar results. It does not appear to be possible to adopt any special methods to prevent these disasters. The simplest method to prevent loss of life seems to be, to prevent the placing of buildings near the front of bluffs, or shores where the unstable clay deposits are liable to be affected by the conditions already indicated. Fortunately, these catastrophes are comparatively rare, and with proper attention to location of houses, or farm buildings, much loss of life can be prevented. The loss of life in connection with the recent calamity at Salette is attributable for the most part to conditions which are not likely to be repeated, if proper precautions are taken as regards the location of residences; while the high agricultural value of many of these clay flats is such that their abandonment would be a great hindrance to the general development of the country.



Map of area showing position of landslide at Notre-Dame de la Salette. The area between the river and the irregular heavy black line opposite the valley plunged into and across the river.

PLATE II.



Looking north over zone of destruction (*a*).

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VERSITY
OF
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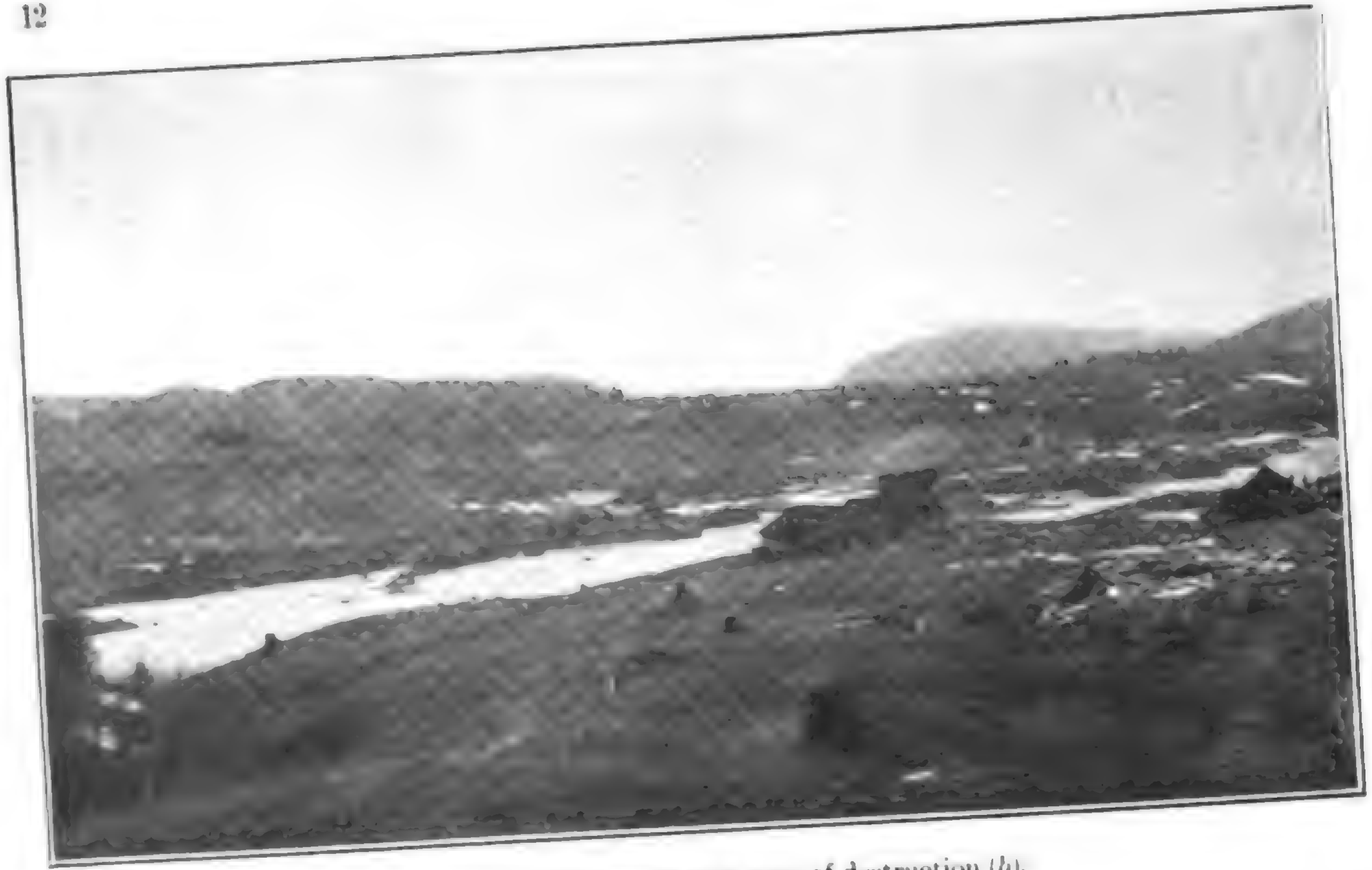
PLATE III.



Looking north over zone of destruction (*b*).

RARY
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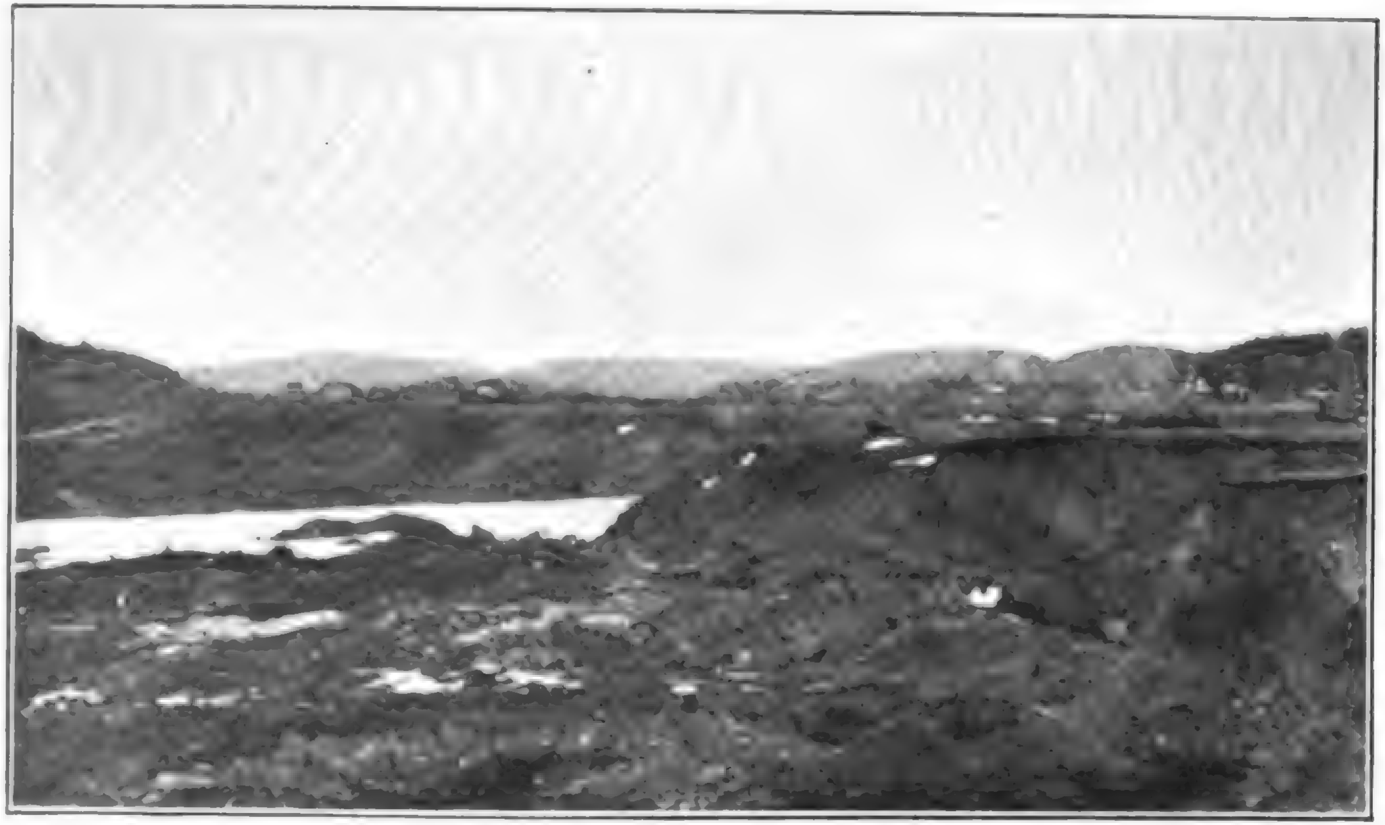
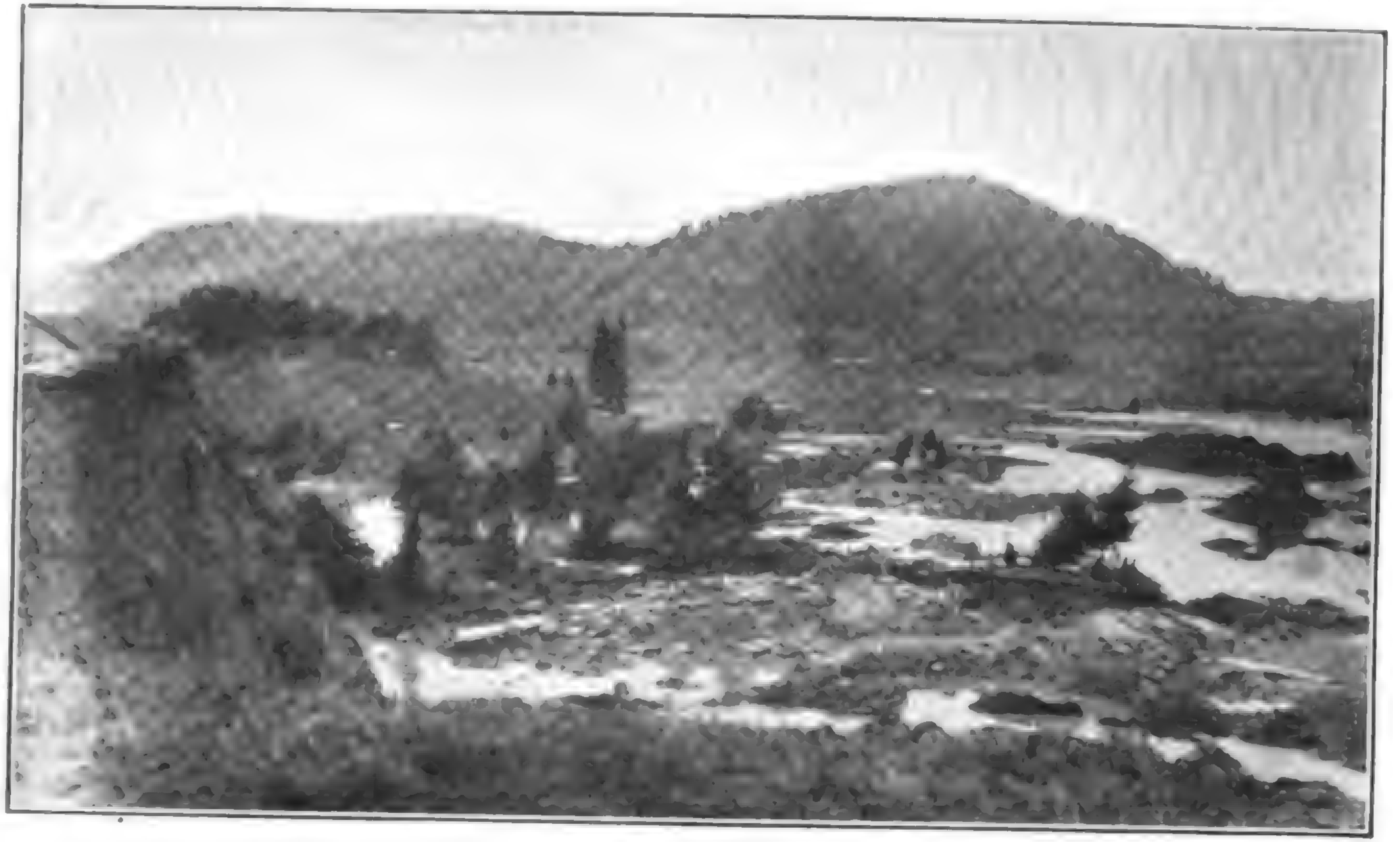


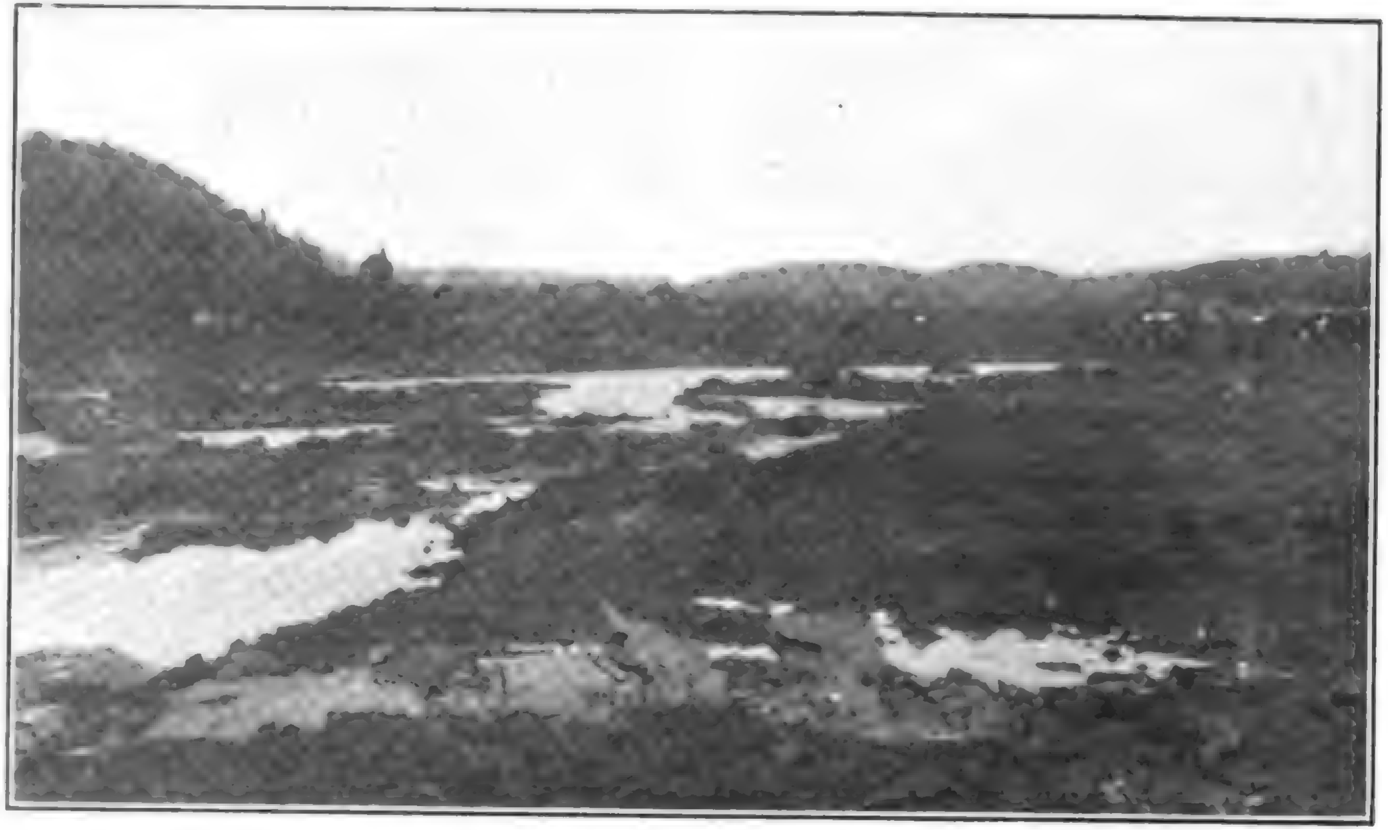
South end of landslide showing fractures from which the mass broke away.

PLATE V.



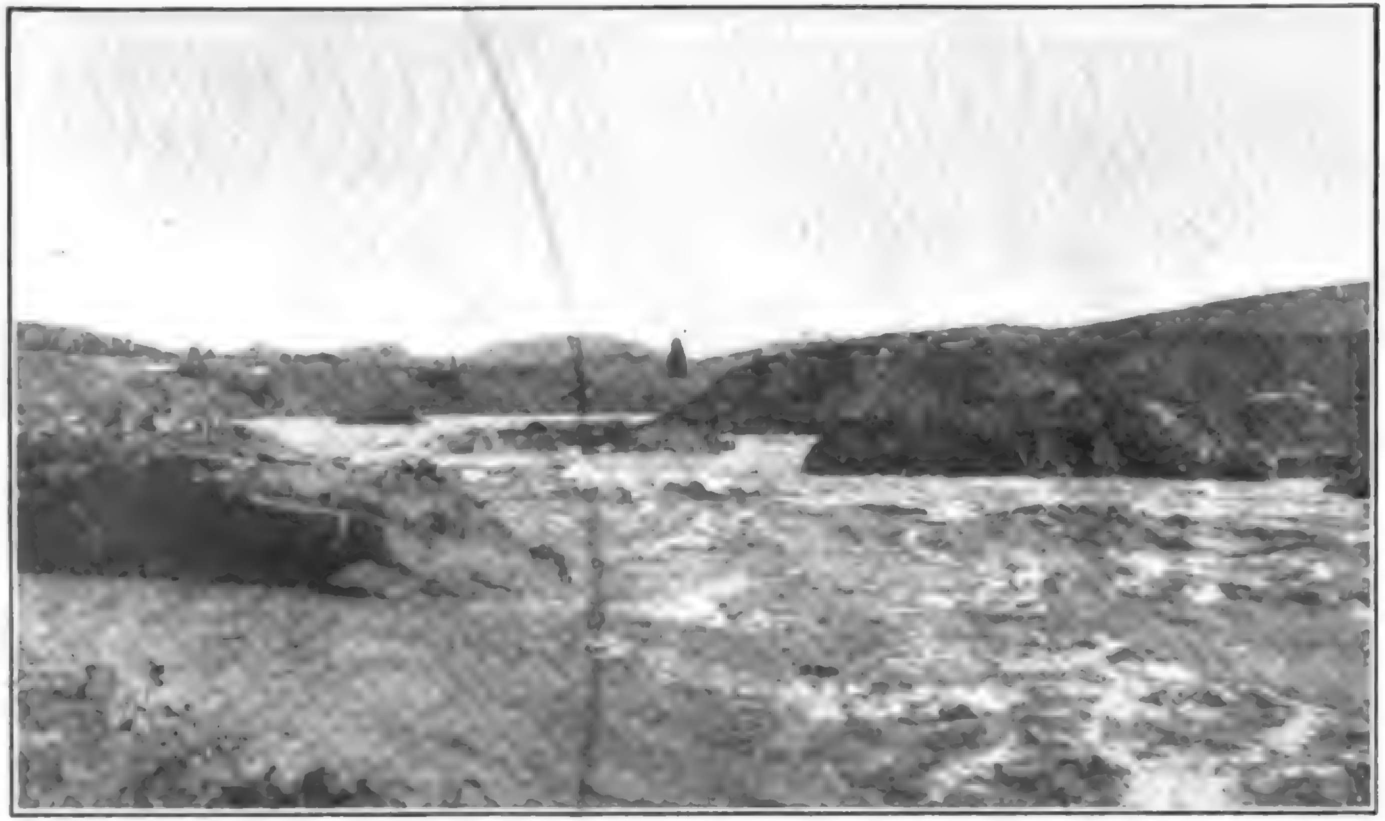
North end of landslide.

UNIVERSITY



Centre of landslide.

PLATE VII.



Channel looking down stream from east shore.
The mass broke away from the clearly defined face of the higher cliffs shown on the right hand.

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A. P. LOW, DIRECTOR.

REPORT

ON THE

COPPER DEPOSITS

OF THE

EASTERN TOWNSHIPS OF QUEBEC

WITH A

REVIEW OF THE IGNEOUS ROCKS OF THE DISTRICT

BY

JOHN A. DRESSER, M.A., F.G.S.A.

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EXCELLENT MAJESTY
1907

No. 975.

A. P. Low, Esq., B. Sc., F.R.G.S.,

Director of the Geological Survey Department,
Ottawa, Canada.

SIR,—I beg to submit herewith a report on the copper-bearing rocks of southeastern Quebec, with a petrographic review of the district. The field work has been done at intervals during the seasons of 1902-3-4-5. The map illustrating this report is based on the survey of the areal geology of the district by Dr. R. W. Ells (Annual Reports of the Geological Survey, 1886, 1887 and 1904).

I have the honour to be, sir,
Your obedient servant,

JOHN A. DRESSER.

Montreal. April 7th, 1906.

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THE DISTRICT.

The district discussed in this report lies in that part of the province of Quebec which is southeast of the St. Lawrence river and south of the city of Quebec. It comprises the counties of Stanstead, Sherbrooke, Compton, Beauce, Sutton, Brome, Shefford, Richmond, Wolfe, Arthabaska, Megantic, Lotbinière, Bagot and Drummond. Being the first part of southeastern Quebec to be surveyed into townships after the English manner of survey, instead of division into parishes according to the custom that prevailed during the period of French rule in Canada, the district is commonly known as the "Eastern townships." As will be shown on a later page, this district is distinguished from the rest of the province by a difference of physical features, as well as by the accident of the mode of survey, and so is a natural division of the country.

The settlement of the Eastern townships began about the beginning of the last century, but it was some fifty years later that the hilly portions became sufficiently opened up by settlement for their mineral resources to be made known. By that time a single line of railway, the Grand Trunk, had crossed the district with a line leading from Montreal on the St. Lawrence to Portland on the Atlantic, and a branch line from Richmond, about the central point of the Eastern townships, had also been extended to Quebec.

I.

COPPER MINING IN THE EASTERN TOWNSHIPS.

The occurrence of copper in the Eastern townships was known as early as 1841. In that year Sir William Logan examined a copper bearing property at Carbuncle mountain, Brompton lake. This was one year prior to the organization of the Geological Survey, of which Logan was the first Director.

In 1847 the Geological Survey report called attention to the deposits at Upton, and the reports of succeeding years mentioned or described other localities, until a compilation of these in 1866 gives a list of about five hundred localities in which copper was known to occur in the district. This mineral was vigorously sought for, and extensively mined between the years 1859 and 1866. With the decline in the price of copper which followed this time, from about thirty-five to nine cents per pound, the mining operations received a very severe check, and work for a time almost completely ceased.

In this earlier work copper was the only product of the ore that was then of any considerable value, and the richest sulphur ores were discarded when the percentage of copper was low. But after the intense speculative wave had passed, notwithstanding the low price of copper, between 1875 and 1885 several properties were reopened, or changed management, and were worked on a better economic basis. Not only were the metallic contents of the ores, except the iron, utilized, but the sulphur was also saved, for the manufacture of sulphuric acid and allied products. Thus the mines at Capelton and Eustis have been worked continuously for about thirty years, i.e. ever since their operations have extended to the utilization of the sulphur. A depth of three thousand feet, or thereabouts, has been reached, and although detailed reports are not available the extension of the plants, and other features observable, indicate no diminishing of the works at those well managed and successful mines.

After remaining unworked for a long interval the property known as the Cillis mine, on lot 4, range XI, of Ascot, was reopened, and operated in the same manner by an American company, and a large amount of valuable ore was produced. This mine, known under the new management as the "Howard," only ceased to be worked after the ore body had been followed across the line into the adjoining property, called the King mine. In the King and Suffield mines the development work carried on by the present proprietor, Mr. A. O. Norton, Boston, Mass., has been very successful A large amount of ore has been exposed and important extensions of the work are being projected.

The Moulton Hill mine, a few miles east of Sherbrooke, was worked at the same time as the Howard and under the same management. It seems to have produced about a thousand tons of ore per month during the last year it was in operation. The Ascot mine, in lot 8, range VIII of the township of Ascot, is another of the reopened properties. Under the direction of Mr. John McCaw, one of its owners, this mine is at present producing an excellent quality of ore.

In short, wherever the mining has been carried on with consistent economy; the characters of the ore bodies properly observed in following the ore; the product of the mines utilized to their full value, and transportation facilities were at least normally favourable, success seems to have followed.

Since the district was first opened the conditions of mining in it have greatly changed. At that time only the Grand Trunk railway crossed the copper-bearing district, and it was from ten to thirty miles distant from the majority of the mines. There have since been added the Canadian Pacific, the Boston and Maine, the Quebec Central, as well as the Orford Mountain, and the Lotbinière and Megantic, two local railways, all of which greatly facilitate transportation for mining purposes. For instance, the mines at Eustis and Capelton, which when opened were seven miles from a railway, are now served by the Boston and Maine railway, which crosses the properties and gives a direct line to Boston and other Atlantic ports. The Suffield, King, Ascot, and several other properties in the southern part of the township of Ascot, which were eight or ten miles from a railway when opened, are at present about equidistant, two miles, from the Boston and Maine on the south and the Canadian Pacific railway on the north. This central locality is one hundred miles from Montreal, three hundred from Boston, and four hundred from New York, with direct lines of railway to each.

The Quebec Central railway reduces the distance of the Harvey Hill mine from a railway, from fifteen miles to seven, and affects most of the other deposits northeast of the St. Francis river in an equally favourable manner. The Canadian Pacific gives access to Roxton and vicinity, and brings the Sweet mine and other deposits of Sutton within one mile of a railway, instead of thirty, as was the case when these were formerly worked. Similarly the Orford Mountain railway has improved the means of access to the copper deposits of Shefford, Ely, and Melbourne.

This opening of the country has not yet proceeded so far as to exhaust the supply of fuel of the district, which, as well as the water supply, is still sufficient for mining purposes. Generating the electricity from a neighbouring waterpower, the Eustis Mining Company employ electric power at their works, and are expected eventually to light their extensive mine by the same means.

Labour in the district has advanced somewhat in price since the earlier mining operations, but is still low as compared with the more recently established mining centres. Mine foremen receive about $2.50 per day, miners $1.50, and labourers, $1.25.

And if to these circumstances there be added the improved methods of smelting, and the altered demands of the modern market, especially for the by-products of the sulphuric acid industry, it will be readily seen that the question of copper mining in the Eastern townships to-day is on an entirely different basis from that of forty years ago.

COPPER DEPOSITS OF THE EASTERN TOWNSHIPS.

The copper deposits of the Eastern townships are of three distinct classes. These are :

1st. Ores, chiefly chalcopyrite with small amounts of chalcocite and relatively unimportant amounts of carbonates, in pyrites. The deposits of this class occur in the porphyry-andesite schists, the oldest rocks of the region. They form lenticular bodies, apparently occupying crevices, or more likely having replaced the rock along lines of weakness produced in the course of the intense regional folding to which these rocks have been subjected. The gangue material when distinct from the country rock is generally quartz, though sometimes calcite.

2nd. Chalcopyrite, bornite, and chalcocite, with small amounts of carbonates, compose the deposits of the second class. These occur as irregular bodies in Cambro-Silurian sediments where the latter are invaded by certain intrusives. The gangue matter is largely calcite.

3rd. Chalcopyrite in pyrrhotite, with a little pyrite, forms the third class. The deposits of this class are situated along the contact of Cambro-Silurian strata with intrusive diabase. They are distinguished from the ore bodies of the second class, not only by the character of the ore and the presence of pyrrhotite, but also by the fact that the second group are generally extomorphic contact bodies, while the third are principally endomorphic features of the contact Moreover the intrusives of the former are only dikes of comparatively small volume, but those of the latter class are large mountain-forming masses. The country rock of the second class of deposits, wherever they have shown any important dimensions, is limestone, with one possible exception, but in the third class it is an iron bearing slate in some cases, and other metamorphic rocks of the district in others.

1. CHALCOPYRITE AND PYRITES DEPOSITS.

In the Porphyry-Andesite Series.

The deposits of this class include the principal properties that were worked in the early development of the district, and all that are at present in operation. They comprise three principal groups:

(*a*) Some fifty mines and prospects, in the township of Ascot, and other townships near the city of Sherbrooke. Amongst these are the Eustis, Capelton, King, Suffield, Ascot and other less known properties.

(*b*) The series of deposits long known to extend through the townships of Sutton, St. Armand, Brome, Shefford, Ely, Melbourne, Cleveland, Shipton, Tingwick, Arthabaska, Chester, Ham, Wolfestown, Inverness and Leeds, as well as the divisions of the seigniory of St. Giles, known as the Handkerchief, and Ste. Marguerite, in the county of Lotbinière.

(*c*) Deposits in the little known district along the boundary line between the province of Quebec and the state of Maine, south and east of Lake Megantic.

It may be seen by reference to the accompanying map that these grounds are in the form of belts, which have a general north-easterly trend, and are approximately parallel. For convenience they may be designated as the Sutton, the Ascot, and the Lake Megantic belts.

In all cases the deposits of this class occur in, or in close association with, altered volcanic rocks, generally of the porphyry class. The country rock is always highly folded, and often twisted and contorted to a remarkable degree, and this deformation gives their shape to the ore deposits. In form the deposits are much flattened lenses, which lie in conformity with the foliation of the rock. They are arranged *en échelon*, generally along zones of extreme foliation. The individual lenses seldom exceed twenty or thirty, feet in width, and bodies of these dimensions would be from two hundred to three hundred feet in length, according to approximate generalization from observation of a considerable number of the smaller lenses, and from the experience of miners who have worked out many bodies. The third axis, that nearest the vertical, follows the dip of foliation. But its length relative to the other axes is not easy to ascertain, even approximately, since it is only those lenses which lie wholly beneath the surface and which have been entirely worked out that can give data of any value, and such opportunities for observation are necessarily rare. Experienced miners soon agree that the dimension of these bodies along the dip is sometimes greater, at others less, than the horizontal axis, and some are of the opinion that it is generally greater.

The arrangement of the ore lenses *en échelon* is a matter of much importance in following the ore bodies. Thus in the Capelton district the miners have learned when a lens is exhausted to drift to the right, to find the next. That is, in proceeding along the strike towards the northeast, each succeeding lens appears on the southeast side of the previous one, *i.e.*, in the hanging wall, and in going towards the southwest the next ore body is to be looked for on the northwest, or in the foot wall. The dip here is from 40 to 70 degrees towards the southeast.

The ore bodies correspond in their arrangement with the order of the hills of the district, and with the general structure of the Appalachian Mountain system, in which each range when it terminates to the northward is succeeded by another lying to the east. It is this orographic feature which gives the Atlantic coast its general northeasterly trend.

Though rarely, the ore bodies, occasionally, cross the planes of foliation of the country rock. They then have the aspect of veins running slightly obliquely to the strike, or more rarely, to the dip of the enclosing rock. These vein-like massses are, however, of very limited extent, and are probably only the filling of local fractures between larger shearing planes. They are perhaps the better developed of the minor series of fracture joints.*

The walls of the ore bodies are not usually well defined, though one is often more definite than the other. The ore, which consists essentially of chalcopyrite in pyrite, grows poorer towards the edges of the bodies where there are no definite walls, until the proportion of ore in the country rock becomes so small as to be imperceptible. From the evidence at present available it can only be said that these ores were primarily brought in by the volcanics in which they are generally found ; that the subsequent folding and shearing of these rocks developed planes of easier passage in which the subterranean waters, leaching out the metallic minerals from the rock, deposited them by replacement of the rock. The better defined wall on the side of the ore bodies may be due to the fact that the rock on one side of a shear plane being more highly fractured than on the other, as is often the case, the greater replacement would take place on the fissile side of the water bearing crevice. Then after the first film of ore had been deposited a protection is afforded by it for the rock face on which it is deposited and all further replacement is likely to be on the side of the more fractured rock. The foot wall is generally the one that is better defined.

---

* J. B. Woodworth, Proceedings Boston Society of Natural History Vol. XVIII p. 397, 1896.

The common occurrence of chalcopyrite in crevices within the pyrite, and as a thin layer upon a joint face, seems to indicate that the chalcopyrite was introduced later than the pyrite. But of this there is not enough known as yet to speak decisively. Actual crystal replacement has not yet been observed.

The average of a large number of assays of specimens from the south side of the Capelton hill, *i.e.* from the Eustis and Capelton mines, and other properties of the vicinity, made previous to 1886, showed the copper to range from 4 per cent to 5 per cent; sulphur, 38 per cent to 40 per cent; and approximately 1 oz. of silver to each unit of sulphur, with small amounts of gold.

A number of assays of recent date from the north side of the same hill, from the Suffield, King and other properties, give a lower percentage of sulphur, but higher metallic values, especially of silver, which here seems to vary without regard to the sulphur. As a very general statement the ores of this class of deposits may be said to carry 4 per cent of copper, 35 per cent sulphur, near the surface, and at greater depths to yield uniformly 3 per cent of copper, 40 per cent of sulphur, 3 oz. of silver, and small amounts of gold.

Gold, which does not seem to be present in appreciable amounts at lower levels, is often an important factor near the surface. Alluvial gold occurs in many of the streams which run over these copper bearing rocks, and the surface rocks yield gold in many parts. At a depth of a few feet from the surface most of such prospects have been abandoned, but in one or two notable instances the gold prospects have been developed into copper mines, through the copper increasing as the gold values decline.

Although it has not yet been found possible to get information sufficiently definite and accurate to make a satisfactory comparison of the ores at different depths there appear to be slightly higher copper, and distinctly greater gold values, near the surface, than at a depth of a few hundred feet. This richer zone seems to be deeper but less well marked in the case of copper than of gold. The information available is, however, insufficient, as yet, to admit of safe generalization. At present it can only be said that there probably are such zones, that they are presumably due to secondary enrichment, and that the enrichment has taken place from above, and hence by means of descending waters. The evidences that both the iron and the copper sulphides were deposited in their present position after the foliation of the country rock began have been already noted.

The source of the copper and other metallic minerals seems undoubtedly to be the volcanic rocks. The principal deposits occur wholly within these rocks, smaller bodies, however, being not infrequently found along the contact of the volcanics with an overlying dolomite. In such cases the copper has evidently been deposited contemporaneously with the dolomite, which it more or less strongly impregnates for a distance of a few feet only from the volcanic rock.

It was recognized by Logan that the copper deposits were derived from the country rock. (Geology of Canada, 1863, pp. 734-5.) But, on the assumption that the country rock was of aqueous origin, they were regarded by him as an excellent example of sedimentary mineral deposits. Thus he wrote (Geology of Canada, 1863, p. 734 et seq.) "The evidence which has been presented in the descriptions of the copper deposits of the Quebec group, appears to show that the metal, like the iron, manganese, nickel and chrome, which so often accompany it throughout these rocks, was held in solution by the waters from which the sediments of the period were deposited. By the agency probably of organic matters it was reduced to the condition of a sulphuret and precipitated with the sediments, either in a finely divided state, or more frequently, in small nodules, or patches, which became interstratified with the limestones, the slates, the diorites, and the other rocks of the series. A subsequent action, probably contemporaneous with that which has metamorphosed and crystallized the rocks over a great part of their extent, dissolved out portions of the copper sulphurets from these beds and in certain cases deposited them with quartz and various spars in the fissures of the rocks; giving rise to the veins or courses which have been described.

"There appear to be, in this region, no facts to sustain the ancient notion of the connexion of metalliferous deposits with eruptive rocks which are absent from great portions of the district."

With the knowledge that the country rock is largely eruptive, and that eruptive rock is present at all the occurrences of copper of any probable importance in the district, the above opinion should evidently be reversed.

2. Chalcopyrite, Bornite, Chalcocite, &c.

Forming Contact Deposits between Cambro-Silurian Limestones and Certain Intrusives.

The ore bodies of the Acton district are the best known of the second class of copper deposits of the Eastern townships. The ores are chiefly sulphides, bornite becoming important, while it rarely, if ever, occurs in the deposits just described.

This group of ore bodies occurs in the vicinity of a series of dikes which extends from Roxton in the county of Shefford to Ste. Apollinaire in the county of Lotbinière, a distance of about one hundred miles. The principal occurrences known are at Roxton, Acton, Upton, Durham, Wickham, Drummondville, Nelson and St. Flavien. The greater part of all the ore bodies, and practically all of many of them, is found in the sedimentary rocks, generally Trenton limestone. But in several instances, notably at Roxton, Nelson and St. Flavien, copper occurs in the intrusive rock, an amygdaloidal diabase. At Upton a little native copper is also found.

At Acton, which has been by far the most important of this class of deposits, a large amount of high grade copper, much of it 30 per cent ore, was produced for several years. The sedimentary rocks at this mine are a magnesian limestone, overlying a black shale. Both are cut by dikes or an irregular intrusion of diabase, or some allied greenstone. The productive part of the deposit was found in the limestone, and when this was passed through the smaller amounts of ore in the shale made the work unremunerative.

In the township of Durham, some twelve miles south of Acton there occurs a body of these ores, the most southerly of the group. It is located near the southern edge of the limestone, which is here only fifty feet thick. The ore supply failed, just as at Acton, when the shaft reached the underlying shale.

Upton, six miles northwest of Acton, is the most remote of the deposits in that direction. Four different properties were at one time worked in this vicinity. None of the workings seem to have reached a depth of one hundred feet. The ore occurs in irregular veins, or stringers in the limestone, which is generally crystalline. It is also finely disseminated through many parts of the limestone. A small amount of high grade ore was obtained by hand picking. No machinery for crushing or mining seems to have been used.

At Wickham, eleven miles northeast of Acton, copper was mined to a small extent. The geological conditions are similar to those at Upton, but the thickness of the limestone was not reached at either place.

At Drummondville, Nelson, and St. Flavien, farther to the northeast, the copper occurs in the intrusive rocks, which seem to form one or more dikes a quarter of a mile in width. The principal work was done at St. Flavien, where several shafts were sunk, and a depth of a hundred feet or more attained.

Although considerable development was carried on at all of the localities mentioned, as well as at some others, no permanent ores have resulted. The fact that the gangue material with the ores of this class of deposits is limestone should make them valuable to mix with the siliceous ores of the other deposits, where even a very low percentage of copper would add to the value of the limestone as a flux.

3. Chalcopyrite in Pyrrhotite.

Forming Contact Deposits between Intrusive Diabases of the Serpentine Series, and Sediments.

The ores of the third class of deposits are distinguished from the others by the predominance of pyrrhotite. Iron pyrites is also present, but chalcopyrite seems to be the only form in which copper occurs in these deposits. They are known to occur at various points along the serpentine belt, especially in the townships of Bolton, Potton, Brompton, Orford, Ham, and Garthby, and are liable to be found anywhere along the contact of the later eruptives of the serpentine area.

The Huntingdon mines, in the township of Bolton, have been the most extensively worked of any of this group. The ore forms a body some eight feet in width at the surface along the inner contact zone of a dike with clastic rocks. There are no structural or other features to suggest secondary concentration of the ore, or that the deposit is other than an original segregation in the magma of the intrusive rock. The ore, of which large shipments were formerly made, is reported to have yielded an average of about 5 per cent copper.

The mine has not been in operation for some years. During the period of its most successful operation the nearest railway was twenty-four miles distant. At present a newly completed portion of the Orford Mountain railway passes within a few yards of the shafthouse.

The properties known as the Bolton and the Ives mines are situated about a mile and a half north of the Huntingdon, and near the village of Eastman, on the line of the Canadian Pacific railway. In the character of their ores, and their mode of occurrence, they are essentially similar to the last. They too are at present closed.

The Lake Memphremagog mine is situated on the northwest slope of Hogsback mountain, two miles from Tucks Landing, in the township of Potton. The development of this property consists at present of a vertical shaft eighty feet in depth, with an adit driven in to meet the shaft at a depth of fifty feet from the surface. The ore-body extends in length for three hundred feet in sight, and exposures a thousand feet apart are probably the continuation of the same deposit. In the adit, which is a cross-cut, one hundred and ten feet of ore are exposed, without the inner limit of the ore body having been reached. This ore varies in the amount of copper it carries from *one* to *nine* per cent. There are also small amounts of gold, generally enough to be appreciable.

In lot 21, range of Garthby, there is a deposit of a similar ore, which is apparently of important size. It is known as the Garthby, or Lac Coulombe mine. A shaft, said to be fifty feet deep, has been sunk, and apparently much of the output remains on the ground. The shaft seems to be sunk in solid ore. The surface stripping has not been sufficient to make it possible to estimate, even approximately, the size of the ore body.

II.

Igneous Rocks of the Eastern Townships of Quebec.

Outline.

1. Area defined.
2. Geography.
3. General geology.

4. Sketch of previous geological research.
5. Petrographical Province of the Eastern townships.
   Sub-provinces: (*a*) Copper bearing volcanics, and associated rocks.
   (*b*) Serpentines and diabases.
   (*c*) Granites.
   (*d*) Later dikes.
6. Petrographical Province of the Monteregian hills.

1.

That portion of the province of Quebec which has been affected by the Appalachian uplift lies wholly to the south of the St. Lawrence river. It comprises two somewhat distinct parts, the mountainous region of the Gaspé peninsula along the lower St. Lawrence, and the hilly country from the Chaudiere river to the International Boundary Line between the province of Quebec and the States of Maine, New Hampshire, and Vermont. The interval between the two portions is marked only by a subsidence in the Appalachian hills southeast of the city of Quebec.

The second of these two areas is commonly designated as the Eastern townships. Being less easily accessible, on account of its hilly character as well as its position, and also less desirable otherwise for settlement, this region was not surveyed until some thirty years after the cession of Canada to England. It was then, accordingly, divided into townships approximately square, and it was further subdivided into ranges and lots, according to the English method, instead of being formed into seigniories and parishes after the old French mode of survey.

The general trend of the hills of the Eastern townships is a northeasterly one, conforming to the direction of the Appalachian folding, the successive ridges growing higher as they are more remote from the St. Lawrence valley. The principal rivers, such as the Yamaska, St. Francis, Nicolet, Beçancour and Chaudière, cross these hills about at right angles to their course, and drain the region into the St. Lawrence.

2.

The tributaries of these rivers, however, take their direction from the Appalachian folds and generally flow in either northeast or southwest courses. The tributaries are, therefore, subsequent to the Appalachian hills, while the main rivers are either antecedent to the later stages of that uplift or have been superposed on the older rocks by the extensive denudations of the region. Hence the tributaries are commonly much younger than the main rivers. From these facts, and also since the course of chief glacial action has been parallel to the valleys of the principal rivers and transverse to the tributaries, it results that many of the latter empty into the former by falls and rapids. The water which these furnish has given rise to several manufacturing centres, as the city of Sherbrooke where the Magog falls into the St. Francis, and the town of Windsor Mills at the junction of the Ouatopekah with the same river. The principal rivers thus give cross sections of the region, while the tributaries usually afford much less information regarding the underlying rock.

3.

With the exception of a few small outliers of Devonian the sedimentary rocks of the Eastern townships are now considered to be Pre-Silurian in age. Silurian strata occur a short distance to the north of the district in question, and small outliers may be found within it, but thus far none such have been definitely determined. To the Cambro-Silurian have been assigned certain of the limestones, the calcareous and ferruginous slates; to the Cambrian, part of the quartzites, greywacké, and the clay slates; while similar rocks, with the exception of the clay slates, are referred to Pre-Cambrian, as well as the large areas of slates that are characterized by the presence of chlorite and epidote.

Igneous rocks are found to underlie the earliest sediments, and to be intercalated amongst them, and to be intrusive through even the latest. Altered volcanics of both acid and basic types are the oldest; while closely associated with them are large areas of stratified rock, which are thought to be in part, at least, much altered tuffs. Serpentines occur amongst the earliest sediments, and probably also cut others of somewhat later age. The diabases and later gabbro-diorites, which are closely associated with the serpentines in position, as well as the granites which lie to the southeast of the Appalachian ridges, and the syenitic rocks of the Monteregian hills to the northwest, are later in age than any of the sediments. Still later than these are the dikes of camptonite, diabase and bostonite, which cut all of the rocks already mentioned, and are themselves little altered in character or disturbed in position.

Extreme metamorphism has obscured or totally obliterated much of the fossil evidence which the sedimentary rocks might otherwise have furnished, while such fossil evidence as there is is rendered less useful for precise correlation by the peculiar conditions under which these sediments have probably been deposited. They have accordingly been designated in geological nomenclature as the Quebec group.*

4.

The group of rocks thus named by Logan and Billings was considered by them to be equivalent to the Calciferous and Chazy formations in part. Subsequently, however, Selwyn and Ells distinguished within the area assigned to the Quebec group the measures now mapped as Pre-Cambrian, showed much of the supposed Silurian to be Cambro-Silurian and classed the greater part of the remaining rocks as Cambrian.

The Pre-Cambrian comprises three main ridges which are the principal physiographic features of the Eastern townships, viz.: the Sutton Mountain, the Stoke Mountain and the Boundary Line hills. These ridges, which are roughly parallel, run in a northeasterly course as determined by the Appalachian folding and are themselves about twenty-five miles apart between the St. Francis and the Chaudière rivers. The rocks composing them were, in the first investigations of the Geological Survey under Sir W.E. Logan and Dr. T. S. Hunt, named argillites, sandstones, chloritic and nacreous schists and slates. In stratigraphical arrangement these ridges were supposed to be synclinal troughs, which had resisted denudation better than the intervening strata.

This view was first questioned by Hunt on stratigraphical grounds, and later by Selwyn, both on stratigraphical and lithological evidence. Dr. Selwyn reached the conclusion that these folded ridges are anticlines, not synclines, and held that the rocks composing them were older than the Quebec group and consequently formed no part of it. The results of the subsequent investigation by Dr. Ells substantiated this view.

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* Sir W. E. Logan, Geology of Canada, 1863, et aliter.

The first igneous rocks recognized in the Eastern townships were the granites of Stanstead and Megantic, the syenitic rocks of the Monteregian hills, Brome and Shefford, and the gabbro-diorites of Brompton, Orford and Ham. These are described at some length in the Geology of Canada, 1863, and have been previously discussed by Hunt.

Both Hunt and Logan regarded the serpentines as altered sediments and correlated them stratigraphically with the dolomites, in view of their magnesian contents. Dr. Selwyn seems to have been the first to point out the probable origin of the serpentines, and also suggested that the stratigraphical questions then under discussion were complicated by the fact that some of the other highly metamorphosed rocks were in reality disguised volcanics. A suite of specimens of doubtful rocks submitted by him to Dr. F. D. Adams, (Annual Report, G.S.C., 1880-81-82) proved the serpentines to be altered igneous rocks generally of the peridotite class, the so-called diorites to be diabases and allied rocks, and some of the other highly altered rocks of the region to be of sedimentary origin.

The re-examination of the areal geology of the district which was necessitated by this information, was entrusted to Dr. R. W. Ells, the results of whose investigations appear in the Annual reports of the years 1886, 1887 and 1894, and in the maps which accompany them.

In these maps the crystalline belts of Sutton and Stoke mountains are represented as Pre-Cambrian in age, and an area along the International Boundary Line is included in the same horizon. The sediments intervening are assigned to the Cambrian and Cambro-Silurian with the exception of some very minor areas which, as has been said, were found to have been occupied with remnants of Devonian and possibly of Silurian measures. The serpentines are included with the igneous rocks and the occurrences of 'basic eruptives' are shown to be more numerous than appeared in the earlier maps. The great body of the Pre-Cambrian, however, remained amongst the sedimentary rocks.

In addition to the accounts of these investigations a few independent papers have been published on this region.

In 1876 Sir J. Wm. Dawson discussed the mode of entombment of certain fossils, referring especially to localities in the Eastern townships. Some of the occurrences of fossils thus mentioned are of essential importance to this investigation.

In 1879 Dr. T. Sterry Hunt in the American Geologist discussed the structure of the region under the title 'The Quebec Group in Geology.'

In 1882 in an address before the Royal Society of Canada Dr. A. R. C. Selwyn first outlined his views of the structure and general lithology of the Quebec Group. (Trans. Roy. Soc. Can., 1882).

In 1902 the present writer showed that important parts of the Pre-Cambrian are composed of volcanic rocks which by their extreme alteration had been previously mistaken for sediments. Their relation to other occurrences of similar rocks in the Appalachian was suggested, and their place in the series described by the late G. H. Williams was pointed out.*

5.

(*a.*) COPPER BEARING VOLCANICS.—(Pre-Cambrian.)

The physiographic structure of the Eastern townships, it has been said, depends on three ridges of Pre-Cambrian rock, which are in the form of rather narrow belts about twenty-five miles apart, running parallel to the axes of the Appalachian mountains. These ridges which rise above the intervening sediments and later intrusives are the crests of once buried mountain ranges, now partially uncovered. Outlying remnants of sedimentary rock are still quite frequently found within these belts.

One of the belts appears for only a relatively short distance along the boundary line between the province of Quebec and the State of Maine. It occurs in the townships of Emberton, Chesham, Clinton, Woburn, Ditchfield and Spalding. From its proximity to the lake of that name it may be designated the Lake Megantic area.

The second crosses the St. Francis river between the city of Sherbrooke and the village of Lennoxville, and is commonly referred to as the Ascot or Stoke Mountain belt. It may be traced from the foot of Owls Head mountain and Lake Memphramagog through parts of the townships of Stanstead, Hatley, Ascot, Ascot Corner, Stoke, Dudswell, Weedon and Stratford. The similar rock at the Gilbert River gold mines, in the seigniory of De Lery, on the east side of the Chaudière river, undoubtedly belongs to this belt.

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* Transactions of the Canadian Mining Institute, Montreal, March 2, 1902. American Journal of Science, July, 1902.

The third of these belts, which crosses the St. Francis river near the town of Richmond twenty-five miles northwest of the last, is generally known as the Sutton Mountain belt. This is the largest and longest of the three as far as is at present known. While the Stoke belt is nowhere more than five miles in width, that of Sutton is quite twenty miles wide at the Vermont boundary line. It has a considerable development in the counties of Brome, Shefford, Richmond, Wolfe, Arthabaska, Megantic, Beauce, Dorchester, and probably extends also into Bellechasse and Montmagny, that is, to a point at least one hundred and forty miles from the boundary of the State of Vermont.

The rocks of the Sutton Mountain area were described by Logan, ('Geology of Canada,' p. 246,) as 'chloritic micaceous and epidotic rocks. Towards the province line,' he continues, 'these are of a slaty character and various shades of colour, from dark bluish-green or blackish-green to ash-grey. The green bands are more abundant than the grey, and both have occasionally a talcoid lustre. The grey bands appear to derive their colour from a large amount of very fine grains of quartz which are uniformly mixed with chlorite. These beds often contain certain nodules of white granular quartz, and crystalline pistachio-green epidote sometimes several inches in diameter, and frequently elongated in parallel directions. The two minerals are often in separate nodules, but as often are intermixed; in the latter case the epidote is generally within the quartz. In the grey bands fine blackish-green lines of chlorite often run parallel to one another, but these are contorted by the nodules of quartz and epidote, with which orthoclase feldspar is sometimes associated. 'Radiated actinolite often occurs in the rocks, together with asbestus in short parallel veins which are found cutting the epidote in the direction in which the nodules are elongated, and occasionally between the layers of slate. Crystals of specular and magnetic oxide of iron are abundant in the chloritic and epidotic bands, the magnetic species being more frequent where the chloritic prevails.'

'Near the St. Francis nodules of an epidotic character are richly disseminated through the chief part of these chloritic strata, some of the nodules being six, eight and even ten inches in diameter. Some of the bands hold small portions of finely granular quartz which occasionally swell into beds of white quartzite of some importance, while many of the strata assume the aspect of fine quartzose conglomerates, or coarse sandstones with a chloritic base."

Regarding the rocks of the Stoke belt, Logan writes (Geology of Canada, p. 252). "The rocks of this group here at the base of Owls Head mountain, branching off from a range of hills which come up from Vermont into Canada, take a northeasterly direction, and crossing Memphramagog lake run from the township of Stanstead through Stoke to Weedon, and constitute the Stoke mountains, which are bounded on each side by more recent strata just mentioned. The average breadth occupied by the Quebec group in these hills seldom exceeds two or three miles, except in Ascot and Stoke. On the St. Francis, in the former township, through the influence of these undulations, the Quebec rocks have a transverse measure of seven miles extending from the vicinity of Lennoxville to the northwest corner of the township, and in Stoke they present two parallel ranges included in a breadth of about five miles."

"In this range of hills the strata consist chiefly of chloritic rocks in harder and softer bands, the softer and more schistose constituting chlorite slates, while the harder may be termed chloritic sandstones. With these are associated micaceous and nacreous slates often presenting a very quartzose character, and thin layers of agalmatolite of a somewhat fibrous texture are sometimes met with. Some of the micaceous and nacreous slates are very fine grained, and on the south side of the range afford excellent whetstones, and hones. Many of the whetstone beds appear to be micaceous slates passing into argillite. Some bands of the slate are studded with chloritoid, and in Sherbrooke they enclose a bed of blood-red jasper, passing into a siliceous, red hematite, and another of a somewhat siliceous conglomerate."

"In the same neighbourhood the nacreous slates are marked by the occurrence of copper pyrites, containing a little gold and silver, in a gangue of white quartz running with the stratification. The chloritic slates are often marked by iron and copper pyrites; and on Haskell hill, on lot 8 of range VIII of Ascot, a band of slate five feet wide holds such a quantity of copper ore as to give promise of a profitable mine."

Selwyn pointed out that slates might be volcanic, as well as sedimentary, but subsequent reports added nothing to the lithologic description of these rocks.

The rocks of these belts consist of two parts, one of which is stratified, and the other unstratified. The latter is a volcanic rock, finely crystalline, and of both acid and basic phases. Quartz porphyry and andesite, or diabase, would originally have been the extreme types. Some of basic phases are altered to serpentine, and all have been highly metamorphosed. It is only by very detailed field study, together with microscopic examination, that the volcanic character of some of these rocks has been ascertained.

Associated with these are stratified rocks of similar material, but which have an original clastic structure. Part contains bands of nearly pure chlòrite, abundant quartz veins, and much iron ore. These are thought to be stratified tuffs, while other rocks, generally more siliceous, as chloritic sandstones and graywackés, are probably true sediments.

Although highly altered the volcanics of this series still show their original characters in localities in which the deformation has been least. The acid phase of the rock is largely a quartz porphyry. A specimen from the hanging wall of the Silver Star mine at Suffield is light grey in colour, and on the weathered surface the quartz phenocrysts are quite conspicuous. Owing to the bleaching of the base the rock has commonly been mistaken for quartzite, or a species of sandstone. The following is an analysis by Mr. M. F. Connor, B. A. Sc., Geological Survey of Canada, of a specimen of the essentially similar rock from the quarry at Sherbrooke, which furnishes road metal for the streets of that city:

Analysis.

SiO_2	70.37
TiO_2	·17
Al_2O_3	11.27
Fe_2O_3	.80
FeO	2.58
MgO	2.03
CaO	2.31
Na_2O	2.63
K_2O	1.86
CO_2	3.60
H_2O	1.96
	99.58

In the thin section it is found to be a porphyritic rock with a finely crystalline base, which contains phenocrysts of quartz and feldspar. The latter are both orthoclase, and plagioclase, the orthoclase being more abundant.

Small rod-like bodies of colourless mica are present in the rock, as well as irregular areas of a rhombohedral carbonate which is apparently dolomite.

Near Lennoxville, on the line of the Canadian Pacific railway, the rock becomes a granite porphyry, differing from the rock just described chiefly in the more advanced character of its crystallization. Farther eastward, where this belt is somewhat wider, the central portion becomes still more coarsely crystalline, and passes from quartz porphyry at the margin to granite porphyry, and finally to a porphyritic granite towards the interior. The latter is the rock of Bald peak, and of other principal hills of the central portion of the Stoke Mountain area, as well as a part of the Pre-Cambrian of Weedon. The basic portion is less well preserved, and its original character cannot be so precisely determined, as there are probably no original bisilicates now present. The decomposition products and traces of the original structure indicate that the rock had, in some cases at least, the character of diabase, while in others it was probably a porphyrite or andesite, rich in ferromagnesian constituents. Areas of serpentine which pass by sharp transition into hornblende porphyrite are occasionally found within the district occupied by this rock. While the alteration to serpentine seems to be complete, no part of the original rock being left, the serpentine has a somewhat different appearance from that derived from the olivine-rich rocks of the larger serpentine areas of the adjoining district. It is distinguished by the 'grating,' or 'bar' structure of serpentine derived from hornblende, or augite, instead of the 'mesh' forms resulting from the alteration of olivine. Small seams of asbestus occur in the serpentine, but although several of the areas have been prospected, no important deposit of that mineral seems to have been found in them.

The acid and the basic phases of these volcanics are not, however, products of separate irruptions, but are due to sharply defined magmatic differentiation. This is well shown in several of the streams that drain the southern part of Stoke mountain—notably on Rowe brook. The rocks may be considered as products of a single flow, or of one flow for each belt. In the Sutton belt, and so far as is known in the Lake Megnatic area also, there is evidence of no later volcanic action. In the Stoke belt, however, later dikes occur somewhat frequently, but they are chiefly of the camptonite and diabase classes They cut the adjacent Trenton sediments, and so belong to a series of rocks to be described later, rather than to those of the present class, as they are not of Pre-Cambrian age.

The Pre-Cambrian volcanics are apparently closely related to those of South mountain, Pennsylvania, and other known localities to the southward and form a link of the more westerly of the two chains of early volcanics that were described by the late G. H. Williams in the 'Journal of Geology,' Jan., Feb., 1894; (See also Ancient Volcanics of South Mountain, by F. Bascom, Bull. U.S.G.S., No. 136).

POSSIBLE PRE-CAMBRIAN SEDIMENTS.—Of the stratified rocks in the metamorphic belt which are most closely associated with these volcanics, the extremely chloritic portions are probably ancient tuff beds, or at least are composed of fragmental volcanic material, and so are pyroclastic rocks. In the present degree of alteration they do not differ essentially from certain portions of basic rocks just described. Besides these are siliceous rocks, quartzites, greywackés and chloritic sandstones, which are possibly true sediments. With these are frequent beds of dolomite, the origin of which seems a matter of doubt. The rock is frequently found resting upon a basic trap, filling pit holes and interstices within it, and enclosing fragments of it. In other cases the rock passes by a rather gradual transition into a quartzose dolomite in masses of considerable extent. At the Eustis mine the portion of the country rock known to the miners as the 'green rock' is of this type. Even in the thin sections small areas of dolomite appear sometimes enclosing small quartz crystals and indicating the secondary nature of the dolomite.

Certain of the micaceous chloritic slates also contain sufficient dolomite to cause a slight effervescence by hydrochloric acid, when heated.

Along the St. Francis river the Sutton belt is some seven miles in its extreme width including nearly two miles of recognized Trenton measures within it. A detailed study shows the volcanics at the base with dolomite, quartzite and grey mica schist, in ascending order. Within the dolomite are certain peculiar inclusions of a bluish grey limestone which have been largely crystallized by intense regional metamorphism. One of these inclusions, however, contains fossil evidence of its Calciferous-Chazy age. It is, therefore, demonstrated that in this part, at least, the Sutton Mountain belt contains no Pre-Cambrian clastics.

As it thus seems certain that the Sutton series contains no Pre-Cambrian clastics in the vicinity of the St. Francis river, it is consequently possible, if not probable, that all the clastic rocks of this series throughout the district are, as in this section, altered members of the Quebec group.

The volcanics are the oldest rocks in this region, and from their lithologic resemblance to the Pre-Cambrian rocks of Pennsylvania and other parts of the Appalachians, they are thought to be of that age. There is as yet no direct proof of this, but the available evidence leaves little room for doubt.

The overlying sediments are always much altered. In some cases the alteration would seem to indicate that these sediments are older than the comparatively unaltered rocks of the basins between the metamorphic ridges, but in other cases they can be traced continuously to rocks of undoubted Cambro-Silurian age. While the different degrees of alteration may in all cases be due to differences of position, or of susceptibility to metamorphism of the various rocks, it is not necessarily the case. Accordingly the question of the existence of Pre-Cambrian sediments in the Eastern townships must yet remain an open one.

(*b*.) SERPENTINES, DIABASES, ETC.

A little to the east of the Sutton ridge, and parallel to it, there is a series of irregular hills which are intrusive through most of the other rocks of the region, generally Palæozoic sediments. They occur notably in the counties of Brome, Sherbrooke, Richmond, Wolfe, Megantic, and probably Dorchester, and are likewise known to reappear in the Gaspe highlands. Amongst them are the Bolton mountain, Owls Head, Orford, Ham and Adstock mountains. The rocks composing them are serpentines, diabase, gabbro-diorites with frequent or smaller masses of hornblende granite, and occasionally much smaller bodies of porphyrite. Of these rocks the serpentine seems to be in all cases the oldest, being cut by intrusions of the other, and possibly it is older than the Palæozoic sediments. The diabases and gabbro-diorites which are phases of the same magma form the greater part of all these hills. They are later in age than the serpentines through which they are commonly intrusive. The hornblende granite in some instances is distinctly intruded through the serpentines, but in one case at least, the Big Ham mountain, it seems unmistakeably to have been differentiated from the parent magma of that rock in situ.

The porphyrite is of limited occurrence; at Shipton Pinnacle, where it is best seen, it seems to cut the serpentine. It generally occurs as the matrix of a band of breccia, seldom exceeding 300 yards in width, that is frequently found along the southern edge of the serpentine belt. As far as it has been studied it seems to be a quartzless porphyrite containing a little hornblende as the only ferro-magnesian constituent.

Mount Orford (2860 feet) is the best known, as well as the largest, of the gabbro-diorite and diabase hills. It has an area of not less than twenty square miles and an average height above the surrounding country of one thousand feet. It comprises two main divisions which give the following cross section measured westward along the line of the Canadian Pacific railway near Miletta : diabase or gabbro-diorite, 7837 feet, greywacké 165 ft., serpentine 577 feet, sandstone 82 feet, serpentine 1567 feet. This section is bounded by sedimentary rocks on either side. The rock of the first and greater mass is a uniform green colour, and shows grey grains on a freshly broken surface. Quartz veins are common and the joint plane and seams are often studded with small quartz crystals. Patches of epidote sometimes as much as a foot in diameter are numerous. The texture of the rock becomes finer towards the outer edge, and also towards the top of the mountain, where the cooling of the igneous mass has taken place more rapidly. In the thin section, this rock, which is exceedingly altered, shows plagioclase feldspar with aggregates of pyroxenic decomposition products, whose relation to one another indicates that the rock has had the structure of a diabase. In the coarser rocks of the central part of the mountain the mineral olivine appears. The rock has the mineral composition of diorite, but the hornblende is secondary and the rock therefore becomes a gabbro-diorite. The two rocks are apparently differentiation products of a single volcanic output.*

Analyses by Hunt (Rep. Geo. Sur. Can., 1853) show the composition of the altered gabbro-diorite and diabase mass, under the head of diorites, to be as follows:—

—	I.	II.	III.
SiO_2	63.40	63.60	63.43
Al_2O_3	12.70	14.20	14.20
FeO	4.23	1.92	1.54
MgO	3.37	6.84	2.35
Ca_2O	7.60	4.37	5.51
K_2O	.13	5.09	2.19
Na_2O	7.95	4.13	3.49
H_2O	.40	.70	1.65
			.87
	99.68	100.85	99.80

I. Diorite, Brompton lake, Orford, Range XVI, Lot 2.
II. Diorite, St. François de Beauce.
III. Grano-diorite, Butte co., Lassen peak, California.

Owls Head (2,465 feet) is situated on the west side of Lake Memphramagog, sixteen miles south of Mount Orford, which stands at the northern end of the same lake. The level of this lake is about six hundred and eighty-two feet above the sea.

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*J. A. Dresser, American Geologist, January, 1901.

The rock at the eastern base along the lake shore is a common basic phase of the Pre-Cambrian volcanics. On the west side the adjacent rocks are sedimentary. Between these the mass of the mountain has been intruded. It consists, as far as yet known, of extremely altered diabase which was first determined by Dr. Adams.

Sugar Loaf, the name by which a continuation of the Owls Head mass towards Orford is generally known, has been also shown by Dr. Adams to be similar in composition. (Rept. Geol. Sur. Can, 1880-1-2, Part A, appended.)

Besides Orford, Owls Head and Sugar Loaf, there are several hills along this line, presumably similar in character. These are Hogsback, between the two mountains last mentioned, Hawk and Bear mountains at the south of Owls Head, and Carbuncle and other hills at the north of Orford. So far as known these hills are similar to Orford and Owls Head in general structure as well as in the character of the rocks composing them. Fifty miles to the northeast from Orford, Big Ham mountain appears as the next prominent point along the serpentine belt, although that belt is almost continuous throughout that distance. The mountain rises fourteen hundred feet above the neighbouring land, or twenty-four hundred feet above mean sea level.

This mountain, as far as known, is a mass of much altered diabase. Near the eastern edge of the summit the diabase passes into a rock intermediate between hornblende granite and diorite, which may be tentatively classed as a grano-diorite. The transition is a rather sharp one, a distance of only a few yards separating typical specimens of the two rocks. The grano-diorite seems to form only a small body, and is probably the residual filling of the neck of the volcano which gave rise to the mass of the mountain.

Moose mountain, in the township of Cranbourne, beyond the northeastern limit of this map, is thought to belong to this series, although there is not much definite evidence concerning it yet available. A specimen from a spur of the mountain in the township of Frampton is a porphyrite, a not uncommon marginal phase of these rocks, and, as Dr. Ells reports the mountain to be intrusive in its relation to the sediments of the district, it may apparently be safely correlated with the diabase series.

Rocks very similar to those of Orford have been described from Adstock mountain, and also from the township of Potton, by Dr. F. D. Adams (*op. cit.*) Dr. Adams found a specimen from the summit of Adstock to be a diabase, and one from another part of the same mountain to be a diorite, both being much altered rocks. Concerning the latter he writes: 'It is a rather coarsely crystalline, massive, and of a greyish-green colour, and is composed of hornblende and plagioclase. The hornblende is green, or, in some places, brownish in colour, and is distinctly plechroic. . . . . It is often twinned. Much of the hornblende is decomposed to chlorite. In many cases the alteration appears to pass through an intermediate stage in which the hornblende assumes a very finely fibrous appearance. The fibres are generally approximately parallel, but do not as a general rule extinguish simultaneously. Individual fibres can often be seen to have an extinction inclined at a small angle to their longer axes. Some of these fibrous grains show a distinct biaxial figure. The plagioclase is dull from incipient decomposition but generally shows well defined polysynthetic twins, of which two sets are frequently present crossing one another. Although the two minerals have interfered with each other in crystallizing, both show good crystal forms. The feldspar is perhaps upon the whole the better crystallized of the two. The fibrous hornblende is found everywhere to be mixed with chlorite.'

The igneous origin of the serpentine was also first pointed out by Dr. Adams in the same publication. In a specimen from Melbourne the rock was found to be wholly reduced to serpentine, with the exception of a few grains of bastite or other mineral derived from rhombic pyroxene. In specimens from townships of Ham remnants of the primary olivine were also found.

The following analyses of serpentine of the Eastern townships are taken from the Geology of Canada, 1863.

——	Orford.	Ham.	Bolton.
Silica	40·30	43·40	43·70
Magnesia	39·07	40·00	40·68
Nickel oxide	·26	.....	.....
Ferrous iron	7·02	3·60	3·51
Water	13·35	13·00	12·45
	100·00	100·00	100·34

Hornblende granite also occurs within this belt and is commonly intrusive through the serpentine. In other parts it seems to form an acid portion rather sharply differentiated from the magma of the parent rock of the serpentine. It has been described by Dr. Adams (*op. cit.*) as composed essentially of quartz, orthoclase, plagioclase, and hornblende, with a little titanic ore. It is also noted as showing a peculiar alteration of the hornblende. Where this mineral comes in contact with the quartz it displays a development of fibrous forms terminating in tufts of fine needles running into the quartz opposed to this marginal facies. The hornblende displays an ordinary even edge when in contact with the feldspar.

Dikes of this rock cutting the serpentine are considered by miners to be indicative of the occurrence of good asbestus. Whether the fracturing of the serpentine accompanying the intrusion of the granite has in any way furnished lines of weakness for the formation of asbestus veins has not yet been established.

Serpentine, apparently quite different in origin, occurs at several places within the porphyry-andesite belt already described. Here, within a distance of ten to twenty feet, well exposed rock may be traced from a quartz-porphyrite to serpentine carrying narrow veins of asbestus. Such occurrences are found in the townships of Ham and Leeds, and several other places within the volcanic belt. So far as yet known none of these are of large extent. That in Leeds is probably half a mile in length. The importance lies, however, in showing the range of magmatic differentiation, and consequently that the quartz-porphyry and serpentine are differentiates of a single original magma. As these are the extremes of chemical composition amongst the various rocks of the region the probability of all being differentiation products of a single primary magma is quite apparent.

(*c.*) GRANITES.

The granites of the Eastern townships occupy six principal areas, none of comparatively great extent. They form the granite masses of Stanstead, Hereford mountain, Big Megantic mountain, Little Megantic mountain, a small area on the east side of Lake Memphremagog, and another near Danville. There are probably numerous other small occurrences in this district, but it is noticeable that all of the granites lie to the south of the volcanics of the Sutton ridge.

None of the granite bodies have as yet been studied in detail, but all are believed to be intrusive through Lower Silurian sediments, and are thought to be of late Devonian age. The extensive quarries at

Stanstead have made the economic importance of that occurrence well known in the province of Quebec, where Stanstead granite is largely used for structural purposes. A specimen of this granite has been described by Dr. F. D. Adams, * and shown to consist essentially of orthoclase, quartz, and biotite, with accessory amounts of microcline and plagioclase, and secondary muscovite and epidote.

Of Hereford mountain nothing definite is known, save that its proximity to Stanstead and the generally similar appearance of the rock in the hand specimen suggest its close relation to that body. Its contact with the sediments is undoubtedly intrusive.

Even less is known of the Big, and the Little Megantic mountains. The material in the talus slopes of the former is a very acid granite.

The granite from Scotstown contains pyroxene, in addition to biotite and muscovite, as ferro-magnesian constituents.

The granite near Lake Memphremagog is also of the type of that of Stanstead.

Near Danville there is a small body of granite whose relation to the surrounding rocks has not been ascertained, nor has it received any detailed study. Biotite is the only dark constituent that is noticeable in the hand specimen. It is mentioned in the geology of Canada, (page 811), that it furnished part of the material for the Grand Trunk Railway bridge which crosses the Nicolet river in the vicinity.

The granite from the quarries at Stanstead shows an incipient cataclastic structure in the microscopic section, and in the mass, a somewhat distinct foliation, known by the quarrymen as the 'rift.' This structure is apparently due to dynamic metamorphism, and shows the granites to have shared in the folding of the Appalachian uplift, and consequently to have been intruded before that movement had entirely ceased. As dikes of adjacent granite masses cut Devonian (Lower Helderberg) strata on the shore of Lake Memphramagog, these intrusives are thought to be of late Devonian age.

(*d.*) LATER DIKES.

A series of dikes of much later age than any of the rocks hitherto described is widely distributed throughout the region. They are comparatively fresh in composition and little disturbed in position. Camptonite, diabase and bostonite are the chief rock types represented amongst them.

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* "Description of a Series of Thin Sections of Typical Rocks," by Frank D. Adams, Ph. D., F.G., Montreal, 1896.

A camptonite* at Richmond was found by the writer to consist of hornblende and plagioclase with magnetite and apatite. A little leucoxene and small aggregates of chlorite, serpentine and calcite indicate that some degree of decomposition has already begun in the rock.

The hornblende is brown in colour, and shows the extinction angle, to be as high as 17°.

This dike, which is about three feet wide, cuts lower Trenton limestone which has been greatly folded and distorted prior to the injection of the dike. One or two smaller dikes occur in the vicinity and a small hill nearby is thought to be underlain by the same igneous rock.

In the vicinity of Sherbrooke, twenty-five miles south of this locality, dikes are known to occur in several localities.

Near the line of the Canadian Pacific railway, in the northern outskirts of the village of Lennoxville, there is a camptonite very similar to the above.

It cuts both Pre-Cambrian volcanics and sedimentary slates of Trenton age.

At the Howard mine, Ascot, a dike of olivine diabase cuts Pre-Cambrian eruptives.

In a paper entitled 'Camptonites and other Intrusives about Lake Memphramagog' (Amer. Geo., July, 1895), Mr. V. F. Masters discusses a large number of dikes in Lake Memphramagog basin, distinguishing the granites, &c., connected with the intrusions off McGoon point already mentioned, from camptonites and allied dike rocks.

Between Roxton in the county of Shefford, and St. Nicholas in the county of Lotbinière, a distance of more than one hundred miles, there are several occurrences of intrusive rock in lower Palaeozoic strata. It is little known except in connexion with copper deposits in the region, which it seems invariably to accompany. It is found at Roxton, Acton, Upton, Durham, Wickham, Drummondville, Nelson, St. Flavien, St. Apollinaire and St. Nicholas, and seems to form a series of dikes in a comparatively narrow belt throughout this distance. The dikes vary in width from a few inches to a thousand feet or even more. and run parallel to the length of the belt in which they occur, *i.e.* in a northeast- southwesterly direction.

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* A hornblende, lamprophyre dike at Richmond, P.Q., J. A. Dresser, Can. Rec. Sec., Jan., 1901.

At Roxton there is a light coloured intrusive of the trachyte class, but in most of these occurrences the volcanics are diabase, and are commonly amygdaloidal.

The largest exposures are at St. Flavien, Nelson and Drummondville. At St. Flavien the intrusion is nearly a quarter of a mile wide and appears to be a wide dike, extending for a distance of about a mile through the country. Similar rock appears at St. Apollinaire, seven miles distant.

These are the principal rock exposures. It is a level district covered with a heavy mantle of drift. The rock is amygdaloidal in many parts, the amygydules being most commonly filled with calcite; sometimes epidote and chlorite or quartz form the filling material. Copper frequently occurrs in this rock, and also at Roxton, Nelson and Wendover, near Drummondville. In other places, as at Acton, Upton and Wickham, the copper occurs in the extomorphic contact zone of the enclosing rock. The exposure at Nelson is smaller than that at St. Flavien, while that at Drummondville is apparently quite as large as the latter.

It is thus described by Logan, (Geo. of Can. 1863, p. 243,). "The greenish sandstones on the St. Francis are intersected by several dikes of diorite, the courses of which are in a general way down stream. The rock of the fall at Drummondville appears also to be a diorite and is of a grey or greenish colour; it probably belongs to the stratification and is not known to have any connexion with the dikes. It has a breath of about half a mile, and some parts are porphyritic from the presence of small crystals of light, greenish feldspar while others are amygdaloidal, holding small portions of a light and calc spar and occasional nodules of agate. Much of it bears the aspect of breccia, in which fragments of the diorite are held together by a close grained but highly crystalline calcareous cement, approaching in colour the general mass of the rock. The rock bears a resemblance to that of St. Flavien, of which it may be a continuation, and like it highly cupriferous.'

So far as yet examined, some half dozen specimens, the diorite of the above description proves to be a fine grained diabase. The diabase forms two bands crossing the St. Francis river here—one having a width of a quarter of a mile and the other of about fifty feet. The distance between them is rather more than a quarter of a mile and is occupied by very dark graphite limestone and greenish grey sedimentary slates. What appears to be devitrified glass was found along the contact of the diabase and the latter rock. These rocks have been here mentioned under the head of 'Later Dikes,' because of their lithological similarity to known dikes, and the absence as yet of satisfactory proof that they are not themselves also of that class. This entire series offers an excellent field for an interesting and important detailed investigation.

6. Petrographical Province of the Monteregian hills.

This name, which has now gained general currency in geological nomenclature, was proposed by Dr. F. D. Adams, in 1903,* to designate a series of volcanic hills which crosses the St. Lawrence valley in the southwestern part of the Province of Quebec. These hills, which are eight in number, are of volcanic origin, either stocks or laccolites; they owe their present relief to differential erosion, and consequently are hills of the butte type.

Six of the eight hills form a nearly east and west line, standing about ten miles apart. In order from west to east they are Mount Royal, at the foot of which stands the city of Montreal (Mont Royal), Montarville or St. Bruno, Belœil or St. Hilaire, Rougemont, Yamaska and Shefford. The remaining stand at the south of this line, Brome being two and a half miles from Shefford, and Mount Johnson, six miles from Rougemont.

The lithological characters of these hills are such as to show them to be a distinct petrographical province, and to bear little, if any, relation to the rocks hitherto described in this article. In every hill there is a large development of essexite, which frequently passes into theralite, and in every one which has been studied in detail, an alkali-syenite such as nordmarkite, pulaskite, or nepheline-syenite. A list of the analyses thus far made from these rocks may serve to indicate their general character.

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* Journal of Geology, vol. xi., No. 3, 'The Monteregian hills, a Canadian Petrographical Province.'

CHEMICAL ANALYSES OF TYPE ROCKS FROM THE MONTEREGIAN HILLS.

—	I	II	III	IV	V	VI	VII	VIII	IX
$Si\,O_2$	48·69	48·85	53·15	44·00	65·43	61·77	57·44	59·96	55·68
$Al_2\,O_3$	17·91	19·38	17·64	27·73	16·96	18·05	19·43	19·12	20·39
$Fe_2\,O_3$	3·09	4·29	3·10	2·36	1·55	1·77	1·69	1·8.	2·10
$Fe\,O$	6·41	4·94	4·65	3·90	1·53	1·75	2·70	1·73	1·95
$Mg\,O$	3·06	2·00	2·94	2·30	1·36	1·54	1·16	65	·80
$Ca\,O$	7·30	7·98	5·66	·94	·22	·89	2·66	2·24	1·92
$Na_2\,O$	5·95	5·44	5·00	2·30	5·95	6·83	6·48	6·98	9·18
$K_2\,O$	2·56	1·91	3·10	·48	5·36	5·21	4·28	4·91	5·31
$Fe\,O_2$	2·71	2·47	1·52	1·90	·16	·74	1·97	·66	·60
$P_2\,O_5$	1·11	1·23	·65	·20	·02	·15	·60	·14	·06
$Mn\,O$	·15	·19	·46	·08	·40	·08	·25	·49	·31
Cl	.....	.....	·07	.....	·04	.....	.....	.....	.....
$H_2\,O$	·95	·68	1·10	·80	·82	1·10	1·03	1·10	1·50
	99·36	100·02	99·84	100·01	99·78	99·97	99·69	100·17	99·83

I. Essexite (Essexose) Mt. Johnson.
II. „ (Andose) „
III. „ (Akerose) Shefford.
IV. „ (Hessose) Brome.
V. Nordmarkite (Nordmarkose) Shefford
VI. Nordmarkite (Nordmarkose) Brome
VII. Pulaskite (Laurvikose) Mt. Johnson
VIII. „ „ Shefford.
IX. Tinguaite (Laurdalose) Brome.

A better knowledge of the igneous rocks of the Eastern townships, especially of the granites and diabases, is necessary before their genetic relations can be satisfactorily discussed. Yet certain general relations may now be deduced, and these conclusions, it is hoped, may be amplified and more precisely applied at some later time when all the rocks in question have become better known.

In general terms it may be said that those rocks of a definite district belong to the same province, (Dr. H. S. Washington, Journal of Geology, Vol. VI and VII, "Petrographic Province of Essex county, Mass."), whose phases in their nearest approach to one another do not differ more widely than the various differentiates of any single mass. Thus the porphyry-andesite series differs in its acid phase from the granites, as far as the latter are known, chiefly in degree of crystallization, not in composition. The more basic phase of the old volcanics, as has been shown, passes by differentiation in situ into a rock which has altered into serpentine. Hence the oldest group seems to form a connecting link between the granites on one hand and the diabases, serpentines, etc., on the other, and, accordingly, these three groups form part of a single petrographic province according to the definition quoted above. The Monteregian rocks appear more distinct throughout the quite extensive range of variation within themselves. The individual hills differ from one another in a comparatively small degree. Also their distinctive characteristics are not yet found in any measure in the other groups of rocks mentioned. Should a detailed study of the granites show that within them are differentiated portions of more basic rocks, as, for example, should nepheline syenite be found in association with them, as it has been found in some cases in the Hastings district by Drs. Adams and Barlow, they would then appear as an acid extreme toward the east of the Monteregian series. But this has not been done, nor is there at present any valid reason for expecting such phenomena to be found. While the Monteregians appear at regular intervals at upwards of ten miles across the plain, no rocks of consanguineous types have been found to the east of Shefford mountain, although a careful examination has been made in that direction throughout the district wherever igneous rocks are known to occur. In the later dikes an indication of rocks of the Monteregian type exists. Though it is conceivable that almost any rock might be differentiated in small amounts from almost any magma, it is the most common relationship to find camptonite and bostonite types differentiated from highly alkaline magmas such as that of the Monteregian rocks. But the wide distribution of these dikes and their relatively small amount make them less important factors in considering the limits of the petrographic provinces. Thus while camptonites and bostonites may occur in many places to the east of the Sutton Mountain anticline, and diabase far to the west of it, as at Drummondville or St. Flavien, they rather illustrate what Prof. Pirrson, (Am. Jour. Sce., July, 1905), has recently called the "progression of rock types," than the extension of the boundary of either of the two distinct groups of rocks mentioned. It would, therefore, seem that the rocks of the Monteregian hills differ from the other rocks described in this article more widely than any of these from one another, that is, that the difference is a generic rather than a specific one. Hence the relation could be best defined as that of two contiguous provinces rather than as parts of one province even in the larger sense.

The study of the consanguinity of rocks tends toward the hypothesis that the interior of the earth may be regarded as containing a single magma of uniform character which, by process of differentiation within the crust of the earth, or during the process of extrusion, or during the process of cooling after extrusion, gives rise to all classes of igneous rock. This is the extreme view of the origin of different species of igneous rocks by the process of differentiation. Partly in opposition to this is that known as the assimilation theory which supposes igneous rocks to owe many of their present differences to the older rocks with which they have come in contact, and by which they have been modified.* This theory could scarcely receive, under any circumstances, such wide application as that just assigned to the differentiation theory, namely, that all rocks have come from a universal common magma and are differentiated only by the rock material with which they come in contact. Nor could it be counted a directly essential character in large extrusive volcanic outputs. But in the consideration of intrusive rocks, where the invading lava may for long periods of time have been slowly taking in and dissolving the surrouding rock material, the process of magmatic stoping may have made the assimilation factor an important one in the modification of igneous rocks.

The Monteregian hills are all intrusive, and are comparatively small igneous masses; they have penetrated strata of different mineralogical and chemical composition. Thus the Hudson River mud stones, Trenton limestones, the graphitic limestone and black slates of the Farnham and Philipsburg series, as well as the quartz mica schists of the Sillery, have been penetrated by these rocks, without producing any material change in the rocks themselves, beyond a generally well marked endomorphic contact zone. Moreover, the sedimentary rocks through which the granites and the diabase series have been intruded are generally very similar to those surrounding the Monteregian hills; in fact, the Hudson River shales are the only rocks of the latter region not found in the former. Hence, it would seem that whatever the cause may be of the primary magmatic differentiation, the magma which gave rise to the Monteregian hills was primarily different from that which produced the other rocks discussed, with the partial exception already mentioned of the later dikes. In summarising it may be said that the rocks of southeastern Quebec present two petrographical provinces, and their differences are due to primary differentiation, i.e. to differences in the original magmas.

I. (a) Porphyry andesite series, extrusive and probably of Pre-Cambrian age.

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* Dr. R. A. Daly, Am. Jour. Sci. On the Mechanics of Igneous Instrusions.

(b) The diabase serpentine group ranging in age from Cambrian to late Silurian or Devonian.

(c) The granites, late Devonian age.

(d) Between these and the next province, in a me bridging over the gap between them, or at least indicating the extreme limit of each has been reached, are the later dik

II. The second province comprises properly only the u group of the Monteregian hills.

ADDENDUM.

For the completion of the investigation which has been br outlined in this report a large amount of field and laboratory wo yet necessary, much of which has an economic importance that is less than its value to pure science. The later dikes are very li known, and yet the occurrence of important deposits of copper in northern part of the district occupied by them has been known fifty years. The granites are a geologic unit concerning which have very little knowledge, and of which correspondingly little u made, while the pyrrhotites of the diabase series promise econo results, perhaps no less important than the asbestus and chromic i deposits, which also await detailed scientific investigation.

CANADA
DEPARTMENT OF MINES
GEOLOGICAL SURVEY BRANCH

Hon. W. Templeman, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Acting Director.

REPORT

ON A

RECENT DISCOVERY OF GOLD

NEAR LAKE MEGANTIC, QUEBEC

BY

JOHN A. DRESSER.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
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MONTREAL, April 23, 1908.

R. W. BROCK, Esq.,
Acting Director,
Geological Survey Branch,
Ottawa, Ont.

SIR,—I beg to submit herewith, a note on the recent discovery of gold near Lake Megantic, Que.

I have the honour to be, sir,
Your obedient servant,

JOHN A. DRESSER.

A RECENT DISCOVERY OF GOLD NEAR LAKE MEGANTIC, QUEBEC.

JOHN A. DRESSER.

◆

LOCATION.

A discovery of gold, which has recently attracted much attention in this district, has been made in the township of Marston in the south-eastern part of the county of Compton, a few miles from the village of Lake Megantic. Megantic station, on the Canadian Pacific railway, between Montreal and St. John, is 175 miles from the former, and 307 from the latter place. It is also connected with Quebec city by the Quebec Central railway, the distance being sixty miles. The place where the gold has been found is in the fifth range of Marston, principally upon lot 19. The distance from Megantic station by road is about eight miles, but this can be shortened to less than six at seasons of the year when the lake can be crossed by boats, or sleighs.

THE DISTRICT.

Lake Megantic is a sheet of water some nine miles in length from north to south, and from a mile to a mile and a half wide. It is drained to the northward by the Chaudière river, which empties into the St. Lawrence river a few miles above Quebec city, after a course of 120 miles. It was on the tributaries of this river, notably the Gilbert, Famine, and du Loup, in the county of Beauce, some forty miles from Lake Megantic, that alluvial gold was successfully mined for many years.

Victoria bay, on the west side of Lake Megantic, and three miles from its northern end, is the most prominent irregular feature in the shore-line. The head of this bay is within a mile and a half of the gold locations. Victoria river, which empties into Victoria bay, is a stream some fifteen miles in length, and has several tributaries, the largest of which takes its head near Big Megantic mountain. Along the Victoria river a considerable number of prospecting licences have been lately taken out; the licence holders evidently considering that the discovery of gold in the rock of the neighbouring hills is a favourable indication of the occurrence of placer deposits in the valleys.

The only other stream of importance emptying into Lake Megantic is the Arnold river, which enters at the head or extreme south end of the lake after a course of fifteen or twenty miles near and parallel to the watershed which forms the boundary line between the province of Quebec and the United States. The mouth of the Arnold is only six miles from the boundary of the State of Maine, and its source is near the headwaters of the Kennebec river, in that State. It has received its name from having formed part of the route followed by General Arnold and his army in the desperate invasion of Canada by way of the Kennebec and Chaudière, to Quebec, in the late autumn of 1775. Several small deposits of copper are reported from the vicinity of this river in the township of Woburn.

The country along the boundary line, and for some distance north of it, is generally wooded. Small farms were opened on the west side of Lake Megantic, forty years ago, and many parts of the district are now cleared. There are, however, considerable areas of spruce forest still remaining, but they are being rapidly reduced by the lumbermen.

GEOLOGY.

The areal geology of this district has been discussed by Dr. R. W. Ells, of the Geological Survey, in the Annual Report for 1886. The map accompanying that report shows the district to the north-west of Victoria bay—including the locality of the recently discovered gold, and the valley of the Victoria river—to be occupied by sedimentary schists, and slates of Cambro-Silurian. They are dark or iron grey, fine grained sediments, with a good slaty cleavage. As their colour would indicate, they contain small amounts of iron ore, and are somewhat micaceous.

They give a rather even surface to the country, which in this vicinity is broken only by the prominent intrusion of Big Megantic mountain. So far as known, this is wholly a mass of granite. It rises abruptly above the surrounding country for 1,500 or 2,000 feet, and occupies between twenty or thirty square miles.

The area between the south end of Lake Megantic and the International Boundary Line, except for some granite hills, is occupied by rocks of a much earlier age; being a part of the Pre-Cambrian formation brought up from the folding of the White mountains. Large portions of it are known to consist of diabase, and other basic eruptives. The intervening section is mapped as Cambrian. It is largely drift covered in the district in question.

The boundaries of the formations, and the strike of the rocks, are north-east and south-west: that is, parallel with the axes of the mountains on the south-east.

The surface of the entire district is generally covered by drift, which carries a large number of boulders—chiefly granite. Exposures of bed rock are few, and of small extent. Yet, the soil is not usually deep, and seems very evenly distributed.

OCCURRENCE OF THE GOLD.

In June, 1905, Mr. Alex. McLeod, of Marsboro, had his attention called by his little son Malcolm to a peculiar rock on lot 19, range IV, which had been uncovered in the operations of putting in the crop. The rock was found to carry native gold in visible amount. After some little exploratory work had been done, protracted negotiations regarding the mining rights followed, and in 1907 prospecting licences on this and several other lots were obtained by Mr. G. A. MacIver of Sherbrooke. Soon afterwards, Messrs. Gendreau, and others, secured licences on several lots, and by the end of November, 1907, prospecting licences had been granted upon some seventy-five lots. In the fall of 1907, the place was visited by Mr. J. Obalski, M.E., Inspector of Mines for the province of Quebec. In anticipation of his Annual Report not yet issued, Mr. Obalski has given a brief account of the occurrence in a more general paper presented at the annual meeting of the Canadian Mining Institute, held at Ottawa, in March, 1908. Mr. Obalski reports that a specimen of the rock, considered by him to be an average of a band seventeen feet in width, yielded $10.40 on assay.

At the time of the writer's visit, in April, 1908, no work had been done for several months, and the pits and trenches were filled with ice and water. Hence, samples showing a proper average of the fresh rock could not be obtained. The ground, however, was practically free from snow, and there was favourable opportunity for tracing out the relations and partial extent of the gold-bearing rock.

The rock which carries the gold at Marsboro is a fine-grained granite, slightly porphyritic in structure, and it occurs in the form of dikes in the Cambro-Silurian slates. Three separate dikes were located. They are between fifteen and thirty feet wide—as far as could be ascertained—and all seem to be about vertical in position. One of them was traced by occasional exposures, for 600 yards. They have been much shattered and broken, and in places are quite schistose. In the cracks thus formed there are many small reticulating veins of quartz, in some of which visible gold occurs. These veins are usually less than an eighth of an inch wide; although one, two inches in width, was seen. The granite of the dikes consists of quartz, and feldspar, with a little muscovite, and in places contains grains of dolomite. Grains of chalcopyrite are frequently found in some parts of the dikes, and a little pyrite and galena are also to be seen. The sulphides are, however, not limited in their occurrence to the little veins, as seems to be the case with the visible gold. The rock is often thickly spotted by iron rust; indicating that iron-bearing sulphides were originally disseminated throughout much of the dike. No gold has yet been found in the slates on either side of the dikes.

In direction, the three dikes are practically parallel. Dike No. 1, on lot 19, strikes N. 60° E. (Magnetic); dike No. 2, which occurs on lots 20 and 21, N. 55° E.; and dike No. 3, on lot 21, strikes N. 60° E. The direction of the cleavage of the slates, in the few places where it could be seen, was found to coincide nearly—if not quite—with the dikes.

On dike No. 1, there are four exposures:—

(A) A cutting about three feet deep has been made, exposing this rock at the edge of the woods which cover the western half of lot 19. Gold is reported to occur here.

(B) Two hundred feet north-east from A, a shaft fifteen feet by eight feet has been sunk and timbered to a depth of sixteen feet. Visible gold can be occasionally seen in the rock of the wall, and of the dump. The shaft was largely filled with ice and water at the time of my visit. This is the place where the original discovery was made, and Mr. Obalski's specimen was taken from this pit. The width of the dike here is seventeen feet.

(C) Five hundred and sixty feet north-east from B, is a cutting six feet deep, from which visible gold is reported. A specimen taken from this place, showing no visible gold, and carrying a few grains of chalcopyrite, was assayed for me by Mr. H. F. Strangways, M.Sc., at McGill University. The results obtained were:—

Gold	0.35 oz.	@ $20.00	=$7.00
Silver	0.70 oz.	@ $ 0.60	=$0.42
			$7.42

A, B, and C are on lot 19, range V, and the width of the dike, as shown at these places, is between fifteen and twenty feet.

(D) Three hundred and seventy-three yards north-east from C, on the farm of Donald Smith, lot 20, range IV, the rock has been uncovered. This disclosure shows the regularity in direction of this dike. There is no exposure of the rock between C and D; but Mr. Smith found the rock at the latter point, by carrying a line in the direction indicated by pits B and C, until his property was reached. Then, sinking through some eight feet of drift, he found the dike rock, which is reported to carry gold.

A, B and C are on the lands under lease to J. A. MacIver and associates. The mining rights at pit D are owned by Donald Smith.

On dike No. 2 no work has been done, and there are only two natural exposures some forty yards apart. The dike appears on lot 20, a few feet from lot 21, and running obliquely towards the boundary line. It probably enters that lot near the more northerly of the two exposures seen. Slate was found on both sides of it, but at some distance. This dike is not less than ten, nor probably more than thirty feet, in width. It is 437 yards northwest from dike No. 1.

The mining rights on lot 20, are held by Mr. MacIver *et. al.*, and those on lot 21 by Messrs. Gendreau.

On dike No. 3, which is forty yards north-west from No. 2, and thus is on lot 21, a cutting apparently five feet deep has been made. Both walls are slate. Mr. A. B. Gendreau, of Lake Megantic, one of the owners, reports that the rock at this place yields a trace of gold.

SOURCE OF THE GOLD.

The gold has evidently been brought in by the granite magma of the dikes in which it is now found; since, as proved by assay, it occurs in the rock as well as in the small veins. The subsequent shattering of the dikes by regional metamorphism has afforded conditions for the concentration of the gold in the small veins in which visible amounts have been found.

EXTENT OF THE GOLD-BEARING ROCKS.

Thus far only three dikes have been found in this vicinity. But as little or no stripping has been done in search of them, since the natural exposures of bed rock are exceedingly few, and as the dikes yet found are near together, it seems likely that there are many others in the vicinity. Their number depends in a considerable measure upon the source of the dikes. Dikes are offshoots from larger masses of related rocks which have filled cracks and crevices formed by the intrusion of the larger bodies. These dikes all trend directly towards Big Megantic mountain, some seven miles distant. This is an intrusive mass which has been thrust up through the surrounding slates, and, as far as known, is of granite; having a chemical, and mineralogical composition that could give rise to such dikes. If Big Megantic mountain is the centre from which these dikes have come, the dikes would then be found more numerous as the mountain is approached. They would also be expected to occur radiating out in all directions around the mountain, but would likely be more numerous and more regular in their direction on the north-east and south-west sides, since these are the directions of the strike of the slates along which cracks would be most easily and regularly formed. For this reason, it would seem advisable to prospect those portions of the townships of Hampden, Ditton, and Chesham which are adjacent to the mountain on the south-west side, as well as the district intervening between Marsboro, and Big Megantic mountain. The long known occurrence of gold in the gravel of Ditton adds weight to this suggestion. If, on the other hand, the dikes in Marston are not connected with Big Megantic mountain, they must come from some subterranean mass of igneous rock. The occurrence of other dikes could not be predicted without more information than is now available. There is, however, no known evidence of importance to indicate that the dikes have such an origin; it is therefore, considered highly probable that they are offshoots from Big Megantic mountain, and consequently, are to be found in various directions around it. Much of the country between Marston dikes and the mountain is wooded, and portions of it a swamp, hence is unfavourable to prospecting.

Rocks similar to the dikes are reported to have been found on lot 26, range III, of Marston, some three miles north-east of the dikes seen, and directly on the line of their strike. There was not an opportunity to verify this. The line of strike carried three miles farther to the north-east, crosses lot 6, range XI, of Whitton, on which tin has been reported in float. Mr. Faribault reports to have observed a dike sixteen feet wide of the same rock crossing the road, ten chains west of Sandy cove of Lake Megantic, on lot 69, range II, south-west, township of Whitton. The direction of the dike is N. 63° E., and dips south-east 75°.

ALLUVIAL GOLD.

Following the announcement of the discovery of gold in the rock at Marsboro, a considerable number of licences have been taken up along the Victoria river. These appear to be held chiefly by placer miners from Beauce. It was late in the season when most of the licences were obtained, and no work of importance has yet been done. With the lowering of the water in the early summer, the valley of the Victoria will probably be well prospected. At the time of writing, no evidence of the value of these prospects is available.

PROSPECTING OF THE DISTRICT.

It must be borne in mind that the gold-bearing rock at Marsboro is as yet known only in small amount, and that the proven occurrences of gold are few. While samples have been taken which appear to represent the general rock of the dikes, and have been found to carry gold, they are after all, only random specimens. Samples representative of each dike must be taken at many points before the commercial value can be distinctly asserted. At present there is no place exposed suitably for the taking of such samples. The dikes are definite bodies, and can be easily uncovered by stripping, and fresh rock could be obtained at a few feet from the surface. Continuous specimens taken across the dikes at suitable intervals would soon make it easily apparent what the possibilities are for profitable mining.

The country is easy of access, and prospecting is not unduly expensive. Once recognizing the direction of the dikes, it is a comparatively simple matter to follow them, as was shown by the discovery of pit D, on dike No. 1, by Donald Smith. If the gold proves to be persistent and at all uniformly distributed in the rock, the district would admit of mining under favourable conditions. Labour is not highly expensive, timber is plentiful, water supply can be had at no great distance, and transportation difficulties are not excessive.

But first, the actual average values of the dike over long distances must be ascertained, and the mode of accurrence of the gold—whether evenly disseminated or unevenly distributed through various parts of the rock—must be found out. And these facts must be determined for each individual dike. Then, if those already found yield values to warrant it, the search for others should be made, as already indicated.

A copper deposit, lately discovered a few miles east of Lake Megantic, was visited with a view to ascertaining whether it showed any relation to the occurrences of gold or not. It is in the sixth range of Ditchfield, on the farm of Alphonse Roy. A shaft has been sunk some twenty-five feet in depth, in a quartzose chloritic slate. The copper occurs as chalcopyrite, and is mixed with pyrite and gangue, in a vein between one or two feet wide. It evidently bears no relation to the occurrence of gold at Marsboro.

LICENCES.

Prospecting licences giving an exclusive right to examine the property, with the privilege of securing mining licences, or of buying mining rights in the province of Quebec, may be obtained from the Honourable the Minister of Mines, Quebec. These licences are granted for three months, and are renewable at the discretion of the Minister. The licence fee in surveyed private lands, as in Marston, is $2.00 per 100 acres, or fraction thereof; a similar fee being required with each renewal. On November 24, 1907, the following lots were held under prospecting licences, in the township of Marston:—

Range	I,	lots	17, 18.		
"	II,	"	19.		
"	III,	"	18-22, inclusive.		
"	IV,	"	18-22	"	and 28.
"	V,	"	16-22	"	
"	VI,	"	13-20	"	
"	VII,	"	12-21	"	
"	VIII,	"	10-14	"	
"	IX,	"	7-14	"	
"	X,	"	7-14	"	
"	XI,	"	4-11	"	and 4.
"	XII,	"	6-10	"	

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#1029

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

Hon. W. Templeman, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Acting Director.

THE GEOLOGY AND MINERAL RESOURCES OF NEW BRUNSWICK

BY

R. W. ELLS

OTTAWA
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A. P. Low, Esq.,

Deputy Minister, Dept. of Mines.

SIR,—Herewith I beg to hand you a report on the Geology and Mineral Resources of New Brunswick. The report is accompanied by a map showing the mineral resources of the province.

Your obedient servant,

R. W. ELLS.

March, 1907.

PART I.

PHYSIOGRAPHY.

The physiography of New Brunswick has been extensively discussed within the last few years by several able writers, including Professor W. F. Ganong,[1] Drs. L. W. Bailey,[2] G. F. Matthew[3] and R. Chalmers,[4] Mr. W. J. Wilson[5] and others. In this brief introduction to the geology and mineral resources of the province it is not therefore considered necessary to give more than a mere outline of the leading features with a view to the better understanding of what may follow.

The province of New Brunswick is the largest of the three that constitute what are usually known as the 'Maritime Provinces.' At one time, with Nova Scotia, it formed what was called 'Acadia.' It is an integral portion of the continent, while the province of Prince Edward Island is entirely surrounded by water. Nova Scotia was in early Post-Tertiary times also an island, though now connected with New Brunswick by a narrow isthmus, only fifteen miles wide, between the headwaters of the Bay of Fundy and those of the Gulf of St. Lawrence. This isthmus consists in large part of marsh, but little raised above the sea-level, and its material has evidently been deposited largely by the action of the tides. Much of this marshy area has been reclaimed from tidal action by an extensive series of canals and dikes and is specially valuable as constituting the finest lands in the province for the production of hay. Reclamation is still going on by artificial methods.

The area of the province is 27,987 square miles. The population according to the census of 1901 was 331,120. New Brunswick, in its general outline, is nearly square, but the northwest portion projects westward between the province of Quebec and the state of Maine for some fifty miles, the River St. John for a part of this distance being the dividing line.

On the south side the province is bounded by the waters of the Bay of Fundy, which extends from the mouth of the St. Croix on the west to the head of Cumberland bay on the east, a distance in a straight line of about 150 miles. On the east it is bounded by the waters of Northumberland strait, the Gulf of St. Lawrence and Chaleur bay, the latter forming the northern boundary of the east coast between Miscou island, which is the northeast point of the province, and the town of Dalhousie at the mouth of the Restigouche river. On the north the Restigouche divides it from the province of Quebec, as far as the mouth of the Patapedia, a distance of about fifty miles, whence the boundary between the provinces westward is broken to its connexion with the upper St. John. From a point about two miles west of Grand Falls the boundary between New Brunswick and the state of Maine is defined by a due north and south line, as far south as what is known as the Monument at the head of Monument brook, which is an upper tributary of the St. Croix river, whence it folllows that stream south to the Chiputneticook lakes, and thence by the St. Croix to Passamaquoddy bay on the Bay of Fundy.

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[1] W. F. Ganong, Canadian History Readings, pp. 74-104-129, 1900.
[2] Bulletins of the Natural History Society of N.B., 1896 to 1907.
[3] G. F. Matthew, G. S. Reports, 1877-8.
[4] R. Chalmers, G. S. Reports, 1884-1894-1899.
[5] W. J. Wilson, Canadian History Readings, p. 137, 1900.

The province is divided into fifteen counties, viz., Charlotte, St. John and Albert, bordering on the Bay of Fundy; York, Queens, Kings, and Sunbury in the interior; Westmorland, Kent, Northumberland, Gloucester and Restigouche along the Gulf of St. Lawrence and adjoining waters; Madawaska, Victoria and Carleton along the St. John river in the northwestern portion. The boundary between New Brunswick and Nova Scotia is along the Missaguash for the greater part of the distance between Cumberland bay and Bay Verte.

The southern portion, including large parts of Charlotte, St. John and Kings counties, is somewhat rugged, the surface diversified by a series of low mountains or hills which rarely exceed 1,200 feet in height. Of these the granite hills which extend across the greater part of Charlotte county are the most prominent in the area west of the St. John, while east of that river the range of crystalline and volcanic rocks, known in part as the Caledonia mountains, rises a few miles east of St. John city and continues into Albert county, terminating about six miles west of the Petitcodiac river. This hilly country extends northward along the St. John river for about thirty miles from the mouth, or nearly to the overlap of the rocks of the central Carboniferous basin.

The central portion of the province is occupied in large part by the Carboniferous rocks, forming an area of not far from 12,000 square miles. Throughout this area there are no prominent hill features, the elevation along the river being very gradual as far west as the city of Fredericton after passing the hilly country along the lower part of this stream. This comparatively low, basin-shaped country extends thence north along the Nashwaak to the Main Southwest Miramichi at Boiestown, which practically marks the northern limit of the Carboniferous formation in this area. The general level of the eastern part of the Carboniferous basin is rarely more than 250 to 300 feet, but in the northeastern portion, between Newcastle and Bathurst, ridges of this formation, indicating anticlinal axes, reach elevations of 500 to 600 feet.

The northern portion of the province, including that part north of a line drawn roughly from the vicinity of Woodstock on the St. John to Chaleur bay, contains the most strongly marked hill features. The country bordering the upper waters of the Tobique, the Miramichi and the Nipisiguit, in which are large masses of granite and other hard crystalline rocks, contains irregular chains of high hills or mountains, some of which reach elevations of not far from 2,700 feet above sea-level. The mountain features in this area have been carefully worked out in recent years by Dr. W. E. Ganong†, who has also spent much time in mapping the orographic details of the province generally. Several high peaks also occur in the area near the forks of the Upsalquitch and Restigouche, as Slate and Squaw mountains with elevations of about 2,000 feet, and at Campbellton in the Sugar Loaf with a height of 950 feet. On the Tobique river the Blue mountains are about 1,725 feet in height, and between this and the mouth of Portage brook on the Nipisiguit there are numbers of peaks with elevations between 1,600 and 2,500 feet above sea-level. To the north of this river the area occupied generally by Silurian rocks is very hilly, and, carefully traversed, may show the presence of masses of igneous rocks.

The rivers of the province are numerous, but small as compared with those of Ontario and Quebec. The St. John, taking its rise in the northern part of the State of Maine, is by far the largest with a length of 450 miles, and draining an area of the province of about 10,500 square miles. Along its course, which crosses the western portion of New Brunswick, there are a number of towns of considerable importance, including Edmundston, Grand Falls, Andover, Perth, Florenceville and Woodstock in the northern part, Fredericton, the capital city, about eighty-five miles by river from its mouth, Gagetown nearly midway to its mouth, and the city of St. John at its entrance into the Bay of Fundy. Numerous small villages are situated also along its course, and in the lower thirty miles above St. John it has in recent years become the favourite place of summer resort, many beautiful cottages having been erected along its banks. These are conveniently situated as regards communication with that city both by railway and by water.

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† Literature.

The river is navigable for steamboats of good size at all times during the season, as far as Fredericton, a daily line of communication being maintained; while above this as far as Woodstock navigation is possible during a part of the summer. In high water, boats can run as far as Grand Falls, which is the first great natural barrier in the river. Above this last point boats can run for another forty to fifty miles, but the facilities for travel along this upper portion by railway, which skirts the bank of the river below Edmundston, have greatly lessened the travel by boats, for this portion.

This river is the great highway for the transport of lumber from its upper waters, both for the northern part of the province and for a large part of northern Maine, huge rafts being sent down to St. John every season. The lower portion especially is a favourite route for tourist travel, the scenery along its course being varied and of great beauty at many points.

Along the lower fifty miles of its course several large bays extend to the eastward, including Kennebecasis, Belleisle and Washademoak, and the Grand lake, a sheet of water about twenty-five miles in length with a breadth of three to six miles, connected with the St. John by the beautiful Jemseg creek. These are all navigable for small steamers, and regular lines of boats ply on these waters during every season.

Among other comparatively large rivers on the west which are tributaries of the St. John may be mentioned the Madawaska rising to the north in the province of Quebec, along the course of which the railway between River du Loup on the St. Lawrence and Edmundston is built, which connects the main line of the Intercolonial with the Canadian Pacific at the latter place. The Grand river, though not large, forms a convenient canoe route to the upper part of the Restigouche, and joins the St. John about twelve miles above Grand Falls; the Aroostook enters on the west side about fifteen miles below that town, but has its course mostly in the state of Maine. The Tobique enters from the east a few miles below this stream and is the principal tributary of the St. John from the east. It extends for some sixty miles in a direct line to the upper waters of the Nipisiguit, to which there is a portage of about three miles and from which there is water communication by canoes with Bathurst on Chaleur bay, a distance by stream of eighty-eight miles. This is a favourite canoe route between the west and east, and both streams are celebrated for the abundance and excellent quality of the trout and salmon which everywhere abound along the whole distance. The scenery along this route is among the finest in the province.

Farther south the Becaguimec and Keswick, comparatively small streams, are found. Opposite the city of Fredericton the

Nashwaak enters from the north and is a large and important stream rising near the upper part of the Main Southwest Miramichi. It is celebrated for the quantity and quality of its lumber. Farther east the Salmon river enters the upper end of Grand lake, the Canaan enters the head of Washademoak lake and the Belleisle and Kennebecasis enter the heads of their respective bays. On the west side of the St. John the Oromocto joins the river about twelve miles below Fredericton and with its two branches, the North and South, drains a considerable area in northern Charlotte and southern York counties.

The rivers entering the Bay of Fundy, with the exception of the St. Croix and St. John, are comparatively short owing to the belt of high lands which keeps a short distance to the north of the coast. West of St. John they include the Lepreau, the Magaguadavic, the Digdeguash and the Musquash, while east of that city they include the Black, the Big Salmon and the upper Salmon rivers. The Petitcodiac, however, which is in the southeastern part of the province, is a large tidal stream for some miles, and at high water vessels ascend as far as Moncton which is a shipping port; while the Memramcook, a few miles to the east, is also tidal, and at one time extensive shipbuilding yards were located near the head of the tidal waters of both these rivers. During low tide both rivers are practically empty with high mud banks, a feature caused by the great rise and fall of the tides along this portion of the Bay of Fundy. From data obtained from the latest published tide tables of the Department of Marine and Fisheries, it is seen that the rise of the tide increases in a marked degree as the bay is ascended, rising from twenty-five to twenty-seven and a half feet for spring and neap respectively in the western portion at St. Andrews to twenty-seven and twenty-three in St. John harbour, thirty and twenty-five at Quaco, forty-one and thirty-four and a half at Grindstone island at the mouth of the Petitcodiac estuary, and forty-five and thirty-eight at the mouth of the Petitcodiac, a rise only exceeded at a few points in Minas basin.

The rivers flowing into the Gulf of St. Lawrence are not navigable for crafts other than canoes beyond their tidal estuaries. They include from south to north, the Buctouche which rises in close proximity to the Canaan; the Richibucto heading near the upper part of the Salmon; with several minor streams between this and the Miramichi. The Main Southwest Miramichi is, next to the St. John, the most important as regards size. It traverses the greater part of the breadth of the interior of the province and heads near the lower part of the Tobique. It has a number of large branches, among which is Cains river from the south, while on the north are the Dungarvon, Renous, Little Southwest and the Northwest, the latter joining the Main Southwest just below the crossing of the

Intercolonial railway near the town of Newcastle. All these rivers are important factors in the lumber industry.

Between this river and the Nipisiguit the rivers are small, but important fishing streams, abounding in sea-trout in their season. They include the Bartibog, Tabusintac, Tracadie and Pockmouche. They are navigable for canoes only for a certain distance according to the state of the water. The Southwest Miramichi and its branches abound in salmon and trout.

The Nipisiguit is an important river. Along its course immense quantities of lumber are floated, while as far up as the Grand falls, twenty miles from its mouth, it abounds in salmon and trout. The falls form an impassable barrier for salmon since no fishway has yet been constructed, though the upper portion would furnish the finest of spawning grounds for this fish. Above the falls to the head of the stream it is one of the best trout streams in the province. It has no large tributaries, the South branch, nearly sixty miles from the mouth, being the most important. This branch heads in the great range of granite hills to the south. Along the lower part near the Grand falls are extensive deposits of magnetite which have not yet been developed.

North of this river several streams, including the Tetagouche, the Nigadoo, the Charlo and the Jacquet rivers are found, none of which are navigable except for canoes in good water, but all abound in trout and salmon.

The Restigouche is the most northerly on this coast. The lower portion flowing into Chaleur bay is a tidal estuary, navigable for steamers as far up as the town of Campbellton, twelve miles above which place it is joined by the Metapedia from the north. Six miles farther west the Upsalquitch comes in from the south, an important stream rising near the Nipisiguit and forming a fine canoe route across this part of the province. Still farther west the principal tributaries from the north are the Patapedia and the Quatawamkedgewick, both Quebec streams. The tributaries from the south are unimportant. All these streams are celebrated for the abundance and quality of the salmon and trout.

The height of land or principal watershed of the province follows a very irregular course. From a paper published some years ago by Mr. W. J. Wilson† the following extracts may be given:—'From the Isthmus of Chignecto (which connects the province with Nova Scotia at the southeast angle) it runs northwesterly almost to the boundary of Kent county, separating the Kennebecasis, Canaan and Salmon rivers from those flowing into Northumberland strait. From this point it runs southwesterly separating Salmon and Cains rivers.

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† Title, 'Canadian History Readings,' 1900.

Then northwesterly in a zig-zag course dividing the waters of the Miramichi from those flowing into the St. John. This course continues into Carleton county where it is only nine miles from the St. John river. The watershed then runs northeasterly between the Miramichi and Tobique waters into Northumberland county. It then curves round again to the southwest into Victoria and Madawaska counties where it is again only ten miles from the St. John which at this point forms the western boundary of the province. The height of land then runs northwesterly into Quebec.

This watershed or height of land is by no means a prominent and distinct ridge through all its course, for in its southern half it is not easily distinguishable. The small streams forming the headwaters of many of the rivers interlock, and it is impossible in passing over the country to determine to which slope they belong without following them for some distance. This is true in a large degree of all watersheds except in mountainous regions. Another watershed of some importance runs through Charlotte and York counties and separates the rivers emptying into the Bay of Fundy from those flowing into the St. John river. Its direction is northwest and southeast.'

Lakes.—While these are numerous none are of large size with the exception of Grand lake already referred to, the area of which is about sixty-eight square miles. The surface of this lake is scarcely above high tide level of the Bay of Fundy, and a small tide is found near its head about seventy miles inland. This is due to the peculiar phenomena of what is known as the 'Reversible falls,' which are situated near the discharge of the St. John into the tidal harbour, where during low tide the river waters are discharged seaward with a descent of fifteen to twenty feet, while at high water in the harbour the fall is inward, the harbour water being then from eight to ten feet higher than the normal water in the river itself. During certain stages in the tide the passage at the falls is smooth and shipping can pass up and down readily. At other times they are of course impassable. The effects of this inflow are felt as far inland as Fredericton. Grand lake lies near the centre of the great inland Carboniferous basin and the shores are generally low and somewhat level. This lake forms the outlet by schooners for much of the coal mined near its upper part in the Newcastle basin.

Among other lakes are those of the Chiputneticook chain on the St. Croix in Charlotte county, the Maguagadavic and Oromocto in southern York and the South Oromocto in the northeast corner of Charlotte, in which area numbers of small lakes occur. Many small lakes are also found around the headwaters of the south branch of the Tobique and the Nipisiguit and in the country drained by the Miramichi. The northern portion of the province shows but few lakes though thickly intersected by streams.

The agricultural capacity of a country usually depends to a large extent on the character of its underlying rock formations. In this respect large portions of the province are of necessity, owing to the presence of masses of granitic and other hard rocks, almost barren since the destruction of the original timber growth which at one time probably covered the greater part of the surface. Much of this timber in the central and northern plateau along the Miramichi was destroyed by great fires, especially by that known as the 'Miramichi fire,' of 1825, in which the soil of the mountain portion was practically burnt off, so that many of these hill ranges are now bare masses of rock interspersed with small shrubs or low bushes only.

The portions best adapted for farming are those underlaid by the slates and limestone of the Upper Silurian formations and by the red rocks of the Lower Carboniferous. Of these the former include a large part of the northern division from a line extending northeast from the vicinity of the town of Woodstock on the St. John river to the headwaters of the Tobique and thence across to Chaleur bay a few miles north of Bathurst. Other areas underlaid by these rocks are found adjacent to the lower St. John. Much of the northern area is still heavily covered by timber, unopened by roads, and consequently almost entirely unsettled.

On the red rocks of the Lower Carboniferous excellent farming lands are found about Bathurst on the north and in the valley of the Tobique; while in the southern part they occur along the valley of the Kennebecasis river, and in parts of Kings, Albert and Westmorland counties.

A large part of the great triangular area occupied by rocks of the Middle Carboniferous of the central and eastern basin, where these rocks are often greyish and sandy, is not largely productive, the resulting soils being light and hungry, but occasionally there are belts of reddish shale which are valuable from the agricultural standpoint. The rougher portions of the province are underlaid by masses of hard igneous rocks, comprising granite, diorite, &c., the decomposition of which is much slower than the comparatively soft sediments of the sedimentary series.

The geological features of the province will be found described in the accompanying report on this subject. They range from Pre-Cambrian, which includes all those of a date earlier than the earliest known fossiliferous Cambrian formations, upward into the upper or Permo-Carboniferous, with small isolated patches of Triassic sandstone and trap. The descriptions of the various economic minerals found in these several formations, with their general distribution, will be found in the accompanying report on 'Mineral Resources.'

The animal and plant life of the province has been described quite fully by various writers. It is not considered necessary to reproduce the results of their studies fully in this paper.

Generally speaking the game animals include the three great divisions of the deer family, the moose, caribou and the red deer, which in the last few years, owing to careful preservation, have become very abundant in all parts of the province. The great area of wilderness lands about the upper waters of the Miramichi, the Tobique and Nipisiguit especially abound with these animals, though in the unsettled portions of Charlotte, Kings, Kent and eastern Queens they are also numerous. Black bears are plentiful and extensively hunted. Among smaller animals (Carnivora) the wild cat, loup cervier, several varieties of the fox, including the red, grey and black, are found in considerable numbers, the mink, martin or sable, otter, raccoon, fisher, ermine and the skunk are also abundant and are hunted for their furs. On the coasts seals of several kinds are frequently observed.

Among the rodentia, the beaver, which had some years ago become nearly extinct, has recently, owing to careful protection, again become fairly plentiful. Porcupines, rabbits (hares) and squirrels, especially the red, flying and ground varieties, the woodchuck and the muskrat abound, though in recent years the black and grey varieties of the squirrel appear to have practically disappeared. Of cetacea, whales are occasionally seen and are sometimes stranded in the shallow shores of the Bay of Fundy owing to the rapid retreat of the tidal waters, while black-fish, grampus and porpoise are also found.

The bird life is numerous. Lists of these were published in 1865, by Professor Hind, and later by Mr. Montague Chamberlain, the latter appearing in the Bulletins of the Natural History Society of St. John, 1882. Valuable papers relating to the physiography, history and general features of the province have also appeared in the bulletins of the same society, the results of the work and investigations of Professor W. F. Ganong.

GEOLOGICAL DIVISIONS IN NEW BRUNSWICK.

COMPARISON OF NOMENCLATURE OF REPORT, 1870-1, WITH THAT OF 1907.

1870-1.	1907.
Laurentian.	Pre-Cambrian, in part igneous and in part altered Silurian and Devonian.
Huronian: Kingston, Coldbrook, Coastal.	Pre-Cambrian with associated igneous masses.
Cambrian, St. John group.	Cambrian, Etcheminian, div. O at base Cambrian divs. 1, 2 and 3.
Mascarene series.	Siluro-Devonian.
Dark argillite series.	Upper Silurian, in part metamorphic.
Pale argillite series.	Devonian, not yet divided.
Devonian:	Bloomsbury division at base.
Bloomsbury,	Dadoxylon sandstone and shale.
Dadoxylon,	Cordaite shale and sandstone.
Cordaite,	Mispeck shales and conglomerate.
Mispeck.	Perry conglomerate, shale and sandstone.
Perry Sandstone group; Lower Carboniferous.	Upper division of the Devonian, including the 'Albert Shales.'
Lower Carboniferous.	Marine limestone, gypsum, conglomerates at base, shales, sandstone, &c. below the Millstone-grit.
Carboniferous: Middle, and Upper.	Millstone-grit, Upper or Permo-Carboniferous of the east coast, the productive coal measures of Nova Scotia being apparently absent.
New Red sandstone, or Trias.	Trias of the south coast.
Intrusive rocks.	Granite, gabbro, diorite and diabase, felsite, &c. of various age.

PART II.

GEOLOGY.

The literature pertaining to the geology of New Brunswick extends over a period of nearly half a century, and expresses the views of nearly a score of observers. It has become at length so voluminous as to be in a manner somewhat unintelligible to one not familiar with the province and the peculiar geological problems there presented. For this reason it has been deemed advisable to produce, in concise form, an epitome of the work done and the opinions held, from time to time, by those who have laboured in this field. This is especially necessary when we consider that no matter how interesting the subject but few persons have the time for careful perusal of all the reports bearing on this special field, many of which also are now not to be obtained, having been long out of print.

In addition to a brief summary of the results obtained by the earlier workers in this field the conclusions arrived at from the latest study of the problems there presented will be given.

The systematic study of the geological structure of New Brunswick may be said to have begun with the appointment, by the Local government, to the position of provincial geologist in 1838 of Dr. A. Gesner, a man of undoubted ability. The results of his labours were presented in a series of reports which may be said to constitute the basis of our knowledge in this direction. The first of these, appearing in that year, embraced the results of his examination of the country bordering on the Bay of Fundy, west of the St. John river, and along that stream as far up as Fredericton. This was followed, in 1839, by a report on the coast district east of St. John extending to the head of Shepody bay, with a brief description of the Tormentine peninsula and the country along the Hammond river. His third season's work embraced generally the counties of St. John and Kings with a very complete description of the Grand Lake coal-field. The fourth described the western portion of the province as far north as Woodstock, on the River St. John, with the country contiguous to that river, as well as the character of the coal-fields lying along the Main Southwest Miramichi river, while the fifth included generally the area lying north of a line extending from Woodstock to Bathurst, on Chaleur bay.

Considering the state of geological science in that early day, the reports of Dr. Gesner contained a large amount of valuable information. It must be borne in mind that the nomenclature of the science was very limited. The grand formation which now comprises the fundamental rocks of our record, the Laurentian, had not then received its now world-wide designation, nor had the term Huronian been even thought of. The divisions into Primary and Secondary, Old and New Red Sandstone, coal measures and granitic rocks, composed the bulk of the geological scale.

There could, therefore, have been no attempt to separate the rocks of the older systems into such an arrangement as now exists. But Gesner evidently did a large amount of good work in the delineation of his areas of coal measures and new red sandstones, his Transition or slate and limestone group, and his volcanic rocks, though many of his boundaries were, of necessity, from the sparsely settled and, in consequence, comparatively inaccessible character of the country, far from correctly laid down, and the stratigraphical order, as given in his reports, is, in some cases, the reverse of what is now known to be the true position.

He pointed out also the presence of the two great areas of granitic rocks which traverse the province, one along its southern portion, the other diagonally across the northern half, extending southwesterly into the State of Maine, where these two areas evidently unite. They were considered by him as of Primary age, and included a large proportion of the felsitic rocks, with which, in some places, the granites are intimately connected. He held that these so-called Primary ridges were flanked by beds of Cambrian age, consisting of slates and hard-grained sandstone, styled by him greywacké, while to the north of the northerly belt the great Silurian fossiliferous area of slates and limestones was clearly indicated. Then, as now, the geology of the southern part of the province was found to be much more complicated than that of the northern portion. The igneous rocks were arranged into two belts, the one composed of true granite and syenite, with mica or hornblende, the representatives of the red granitic areas now recognized in Charlotte county and western Kings; the rocks composing the other comprised a large portion of the old Pre-Cambrian syenites and felsites of the present day, and were regarded as intrusive and as overflowing the schistose strata with which they are associated.

Resting upon the flanks of these intrusive ridges were two great series, one containing the limestones afterwards regarded as of Laurentian age, together with certain slates about St. John, and classed as the lower series; another portion, consisting of sandstones and slates and holding fossil plants and tree stems, was recognized as an upper or newer division. These two groups, the lower of which was supposed to belong to the Silurian system, were held to pertain to the greywacké or transition series and to overlie another area of schists, sandstones, conglomerates, &c., unconformably, which, from an apparent absence of organic remains, was styled Primary.

Concerning the rocks which underlie directly the great central Carboniferous area, the limestones were correctly placed in the lower portion of that system, but the associated red sandstone, conglomerates and marls, together with similar rocks in the valley of the Kennebecasis and Petitcodiac rivers, were regarded as of more recent age and referred to the horizon of the New Red Sandstone; while other red sediments on the St. John river, near Hampstead, were regarded as older and of the age of the Old Red Sandstone. The areas of soft red sandstones and shales along the Bay of Fundy, at Quaco and at other points east of St. John. were also regarded as of New Red Sandstone age.

Reviewing the reports of Dr. Gesner one can hardly fail to be impressed with his evident desire to convince the government, and through it the people, that the mineral resources of the province were practically limitless. This is more particularly the case in regard to the central coal basin and the iron ore deposits of Kings and Queens counties; and this feature has been ably criticized by the late Dr. Robb in his subsequent report on the coal-fields of the province, published in the report of Professor Johnson on the agricultural resources of New Brunswick, in which he clearly points out the unwarrantable exaggerations of Dr. Gesner as to the boundless stores of mineral wealth.

Doubtless many false hopes were raised by this unwise policy, and ground was given for much unprofitable controversy, before the true geological relations of the Carboniferous rocks were finally established. To his researches, however, we must ascribe the discovery of that wonderfully rich mineral deposit called generally 'Albert coal,' and concerning the true character and composition of which he appears to have had a just judgment, regarding it as an altered asphalt in the face of the combined opposition of the majority of the leading scientists of the day.

It is unfortunate that although Dr. Gesner spent the greater part of five years in his preliminary surveys of this province his labours ended without the publication of any geological map which might embody the result of the very large amount of exploratory work he evidently accomplished; and this is the more to be regretted since many of the points so graphically described by him lose, in consequence, very much of their actual value to the general reader.

Following Dr. Gesner, the next writer on the subject was the late Dr. Robb, of King's College, Fredericton (now the University of New Brunswick), who, in 1849-50, published a geological map which is embodied in the report of Professor Johnson, already referred to, and contributed a chapter to that work. Comparing this map with the reports just described it will be seen that a considerable advance has been made both as regards stratigraphy and nomenclature. The Primary and Transition groups are now arranged under the head of Cambrian and Lower and Upper Silurian, but no distinction was made in the red-coloured sediments, the whole being massed under one heading, though comprising areas which range from the Devonian to the top of the Upper Carboniferous. He, however, clearly understood the true position of the Lower Carboniferous sandstones and conglomerates as underlying the coal measures—from which arrangement Dr. Gesner dissented.

The belts of granite, both of the northern and southern areas, were indicated roughly, but much of what is now called Pre-Cambrian, embracing a great thickness of volcanic rocks, was included under the head of traps, syenites, feldspar-porphyries, &c.; while the Cambrian rocks were supposed to include, not so much the recognized Cambrian of the present day, as what are among the oldest of the Pre-Cambrian rocks, viz., the limestones, syenites and gneisses, with associated slates at one time regarded as a part of the Laurentian system. The limits of the central Carboniferous basin were outlined with considerable correctness, and the various coal crops clearly defined.

Dr. Robb also seems to have perfectly understood the general unproductiveness of this area, and to have vigorously confuted the exaggerated statements previously made concerning its economic importance.

In the northern portion of the province the boundaries of the great Silurian area north of the Tobique river, in so far as accessible, were quite correctly delineated, though, as communication was necessarily difficult, the various geological features were otherwise, for a great part of the area, largely conjectural.

Following the publications of Dr. Robb the next papers on the subject are brief articles by Messrs. Jackson and Taylor, bearing principally upon the disputed mineral of the Albert mine. These appeared in 1851, and were succeeded in 1852 by another, published in the *Geological Journal*, London, on the structure and geological relations of this famous deposit, by Mr. J. W., afterwards Sir William Dawson.

Perley's Handbook for Emigrants, while containing some information concerning the geological structure of the province, can scarcely be said to have advanced our knowledge greatly; since the remarks there contained were taken largely from the works of previous writers. But in 1855 the first edition of the Acadian Geology contained two chapters relating to this province, the former of which, pertaining to the Carboniferous system, is a valuable contribution, and the conclusions there expressed as to the horizon of the central area, as well as the divisions of the southeastern portion in Albert county, have been very fully confirmed by the most recent investigations.

Concerning the older series of rocks developed about St. John sufficient work had not at that time been done to determine their true age. The richly fossiliferous Primordial or Cambrian slates of that city and of the Hammond River valley to the eastward had not then been studied; and only a few imperfect remains had been found, whose age could not be ascertained. As a consequence the Pre-Cambrian age of the rocks which unconformably underlie these at many points could not be established, while opportunities for comparison between the crystalline portion and the recognized Laurentian and Huronian of Ontario and Quebec, which, through the labours of Logan, Murray and Hunt, had now come into great prominence, were not sufficient to establish their true position on lithological grounds. The conclusions on this area then stated, in default of extended personal observations, were therefore of necessity largely those of Dr. Robb, who at that time, and in fact for some years later, was regarded as the standard authority on New Brunswick geology.

During the succeeding years to 1860 but little geological work appears to have been done, except in a desultory way; but about that date several young gentlemen of St. John, notably Messrs. Hartt and the brothers G. F. and C. R. Matthew, began the careful systematic study of the rock formations about that city. They were ably assisted by Professor L. W. Bailey, who had lately been appointed to the chair of Natural History in the University of New Brunswick, which had become vacant through the death of Dr. Robb. These gentlemen were fortunate in discovering a rich fauna and flora in many of the beds, both in the city itself as well as at various points to the east and west. The collected fossils were submitted to Sir J. W. Dawson, the principal of McGill College, and the recognized authority on fossil botany, who speedily determined the horizon of a portion of the strata as Devonian, while the fauna of another portion clearly appertained to a much older period. The results of these examinations were first made public in a paper read before the Natural History Society of Montreal, in 1861, and the Devonian character of the flora fully stated. In the same paper, however, the author stated that the associated slates and limestones, regarded by

Robb as Cambrian, but whose relations had not been clearly made out, might possibly belong, on stratigraphical grounds, to the Devonian or Silurian. These results were also communicated, in a much more extended form, in a paper to the Geological Society of London, published in 1862; in which also it was stated that the Devonian might possibly include what is now known to be Primordial, as well as the so-called Laurentian gneisses, limestones and associated rocks.

It will thus be seen that the geology of this section was an exceedingly difficult problem to decipher and one requiring great stratigraphical skill, as well as extensive knowledge of the obscure fossil forms that were being discovered from time to time, the horizon of which had not yet been accurately determined; and it was not until several years later that light began to break in upon this intricate question; for in the next publication on this subject, which was a communication from Mr. G. F. Matthew to the Canadian Naturalist in 1863, while re-casting the groups, as stated by Principal Dawson in the previous year, and giving them local names, he failed to see any real ground for the separation of the metamorphic portion, comprising the limestones, gneisses, &c., from the fossiliferous Devonian. He, however, gave the name of 'Portland,' to the lowest members of the group, from the fact of their being extensively developed in that suburb of St. John, and assigned them to the horizon of the lower Devonian, or possibly the upper part of the Silurian system.

To an apparently overlying series, embracing a considerable thickness of greenish grey slates, red, slaty conglomerates and shales, with red conglomerates, grits and hard grey sandstone, the name 'Coldbrook' was given, while a third division, styled the 'St. John group,' comprised a series of dark grey slates and sandstones, to a great extent the Primordial of the present day, in which were found a lingula and several other obscure fossils.

His succeeding group, the 'Bloomsbury,' while largely of volcanic origin, included in its upper part some five hundred feet of slates and conglomerates, apparently devoid of fossils; overlying which came the Little River and Mispec groups, largely composed of sandstones, slates and conglomerates of various colours, but distinguished in places by a great abundance of fossils, principally plants, though comprising also crustaceans and the remains of insects.

The apparent difficulty of separating the metamorphic portion from the fossiliferous and recognized Devonian, arose in great measure from the seeming interstratification of the various groups, and the complicated structure arising from the enfolding of newer strata with those of great antiquity, due to a series of anticlines which are often completely overturned, in conjunction with profound faults; and it was not until the researches of another year by those indefatigable workers, Messrs. G. F. and C. R. Matthew, that the beds which the former gentleman had designated the St. John group, and which had for a long time been known to hold certain obscure traces of organic life, disclosed a new and entirely unexpected suite of fossils. These included brachiopods and trilobites, the latter in considerable variety, but generally of small size, which, on comparison with the published memoirs of Barrande on the Primordial of Europe, resulted in the establishment of a similar Primordial zone in New Brunswick, a discovery, the importance of which in relation to the elucidation of the geology of this section, can scarcely be overrated.

The credit of solving this difficult problem is largely due to the late Mr. C. F. Hartt, one of the earliest and most zealous workers in this field, who at that time was engaged in the Museum of Comparative Zoology in Harvard College. The results of his investigations on the fossils collected by the Messrs. Matthew in 1862, and by himself in the following year, were communicated in a preliminary paper to Professor Bailey in 1864, and published in the 'Observations on the Geology of Southern New Brunswick' by that author in 1865.

The discovery of the Primordial or Cambrian zone in the vicinity of St. John worked an entire revolution in the stratigraphy of that portion of the province. The puzzling admixture of the most highly metamorphic rocks with those entirely unaltered and abounding in fossils was again investigated, and by the aid of the new light a tolerably clear knowledge of the structure was obtained. The map accompanying the report just referred to, as compared with the hitherto recognized standard of Dr. Robb, shows many important changes in the various geological formations. One of the first corrections made was the transposition of the crystalline limestones, gneisses &c., from their former doubtful position to their proper place below the Cambrian, which was found to overlie them unconformably at various points; whilst their resemblance to recognized Laurentian rocks of Ontario and Quebec, which had already been pointed out by Sir William Dawson, rendered it exceedingly probable that they might occupy a similar position in the geological record. They were, therefore, so arranged, and have since been regarded by most geologists, as among the fundamental rocks of the province.

The lithological characters of the various rocks which compose these Azoic or Eozoic strata have been given in different papers on the subject. Their high degree of metamorphism was commented on by Sir William Dawson as early as 1861, and the descriptions of the several divisions of slates, limestones, quartzites, syenites and gneiss were subsequently stated in Professor Bailey's report in 1865, under the heading of the 'Portland group,' and will be considered later.

Following the paper of Mr. Matthew in 1863, on the rocks in the vicinity of St. John, appeared one by Professor L. W. Bailey in the Canadian Naturalist, detailing observations made in 1863 during a canoe voyage across the northern part of the province, by way of the Tobique and Nipisiguit rivers. The paper is of special interest as giving us the first scientific account of the geology and botany of the country along these streams; since on the map of Dr. Robb, while the areas of Upper Silurian and Lower Carboniferous on the Tobique were laid down with tolerable accuracy, the boundaries of the formations on the other streams flowing east to Chaleur bay were largely imaginary. The great areas of felsites and other crystalline rocks about the headwaters of the Nipisiguit were noted by Professor Bailey, though their age was not determined, and the Lower Silurian aspect of the strata on the lower portion of this stream was pointed out. This was followed in the same year, 1864, by his 'Notes on the Mineral Resources of New Brunswick,' which, while giving nothing specially new in reference to the geology, contained much interesting matter concerning the mining industries, then in their infancy. It was in turn followed the next year, 1865, by two reports on the geology of the province, the first by Professor Bailey on the southern portion already alluded to, and the second by Professor H. Y. Hind, also on its general geology, but more specially of interest in reference to the northern portion, and containing much information on the minerals of economic value. In both of these a marked increase in the nomenclature of the science is manifest. The researches of Prof. Hartt on the Primordial, already noted, led not only to the separation of a portion of the crystalline rocks as Laurentian, but made a still further stride by the removal of a second portion, lying stratigraphically between the Laurentian and the Cambrian, which was erected into a distinct group with the title of Coldbrook, and assigned to the Huronian system. This division was in time subdivided into an upper and lower, the former of which, consisting largely of reddish strata, was regarded as of purely sedimentary character, while the latter, composed largely of hard, greenish rocks, was held to be chiefly of volcanic origin, the thickness of the whole being estimated at 5,000 feet.

The recognized areas of Huronian rocks were, however, as yet very limited. The intricate stratigraphy of the south coast still prevented the separation of much of what is now known to be of that age from the position it had so long held as presumably Devonian or Silurian. From their apparently interstratified position among the plant bearing beds of the former, at several points east of St. John, it was inferred that a great thickness of strata, highly metamorphic in character, and now known to be among the oldest in the province, constituted an integral portion of that series.

This belt, which has an extensive development in eastern St. John, Kings and Albert counties, has since been found to unconformably underlie rocks of Primordial age.

Another great group of rocks, also for the most part highly metamorphic, and designated by the term 'Kingston,' was brought prominently into notice in the same report. More difficult, apparently, of location than even the Coldbrook, its exact position could not, at that time, be determined by the New Brunswick geologists, and a suite of specimens was accordingly submitted to the inspection of Sir J. W. Dawson and Dr. Hunt of Montreal.

The lithological characters of the group were stated to be very like those found in the rocks of the Cobequid series of Nova Scotia, which were then regarded as of Upper and Middle Silurian age. It was also stated that possibly portions of the group might pertain to the Devonian system, from their resemblance to the supposed Devonian of southeastern New Brunswick, while the similarity of many of the rocks to older or true Plutonic masses was also pointed out. The true position of this group of rocks, which has a considerable development in the southern part of the province, will be considered later.

The Devonian of this area, as described in the report in question, has, since its publication, been greatly modified. It became evident, as the relations of the Huronian and Primordial were more fully understood, that a considerable thickness of what was styled the Bloomsbury group, which represented the lower portion of the Devonian, possessed lithological characters very similar to much of what was now called Coldbrook, and that it was separable into two parts, the upper of which only,—embracing some 500 feet of sandstones, shales and conglomerates,—was referable to the Devonian; the lower portion, which was largely volcanic, being transferred to the Pre-Cambrian.

The Little River group, the second division, was also clearly separable into two, the Dadoxylon sandstone and the Cordaite shales; the former of which, consisting for the most part of hard grey sandstones, shales and grits, and representing a total thickness of about 2,800 feet, was characterized throughout by a wonderfully rich and important flora, of which large collections were made and carefully determined by Sir J. W. Dawson.

The second subdivision of the Little River group was, in 1865, held to embrace rocks of very dissimilar character. In addition to fine shales and sandstones, holding the remains of Cordaites from which the formation received its name, it was thought that a great thickness of metamorphic rocks, chloritic and talcose schists, felsites, &c., presenting a marked resemblance to strata, which at a later period were recognized as Huronian, constituted, from their supposed position upon the Dadoxylon sandstone, an upper part of the same series.

This view was entertained for some years, or until the subsequent study of the formations on the east side of the St. John harbour disclosed the fact that the apparent position of the metamorphic upon the unaltered portion was due to an overturn, or possibly to a sliding fault. The error thus stated in 1865, and repeated by Professor Hind in his report in the same year, was again reproduced in the geological map which accompanied the second edition of the Acadian Geology in 1868; but it was soon afterwards discovered by the local geologists, and the metamorphic portion was separated, and established as a division of the Huronian, under the title of the 'Coastal group.'

The supposed highest beds of Devonian age were arranged under the head of the Mispec group. They consisted principally of reddish conglomerates and slates, the former holding fragments of felsitic rocks, red sandstones and slaty limestones in a reddish slaty paste. These were not found to contain fossils.

Passing to the consideration of the next system we find the general outlines of the Carboniferous indicated with tolerable accuracy. The observations appear, however, to be largely directed to the structure of the lower division; which, more especially in its eastern extension, included considerable areas of the middle Carboniferous. Sufficient opportunities for study were not afforded in this direction to admit of their complete separation. The various subdivisions of the Lower Carboniferous, as there laid down for the eastern part of Albert county, were verified on subsequent detailed examination, though certain sections elsewhere appeared at first view to present a somewhat different arrangement; more especially in regard to the true position of the bituminous or 'Albert shales,' which were later found to be unconformably beneath the marine limestone of the Lower Carboniferous.

In its distribution the Lower Carboniferous formation was found to constitute a well defined belt, underlying, throughout its whole extent, the Middle Carboniferous basin of the interior. It also comprised certain areas in eastern Albert and Kings counties which rested upon the flanks of what was then regarded as the metamorphic Devonian of the Caledonia Mountain range. West of St. John, however, its presence was not definitely noted, certain rocks in the vicinity of Lepreau village and harbour, which had been regarded by

Dr. Gesner as of New Red Sandstone and Carboniferous age, being found to pertain to a much lower horizon, representing the upper part of the Devonian system.

Concerning the structure of the central or Middle Carboniferous basin but few additional details were added to the views already expressed by the late Dr. Robb. Fossil plants were obtained at points about Grand lake, as well as in the vicinity of the Miramichi river and Chaleur bay, which appeared to present what was at that time regarded as a mingling of forms, including some portions even of the Upper Carboniferous, while fossils from other outliers of the formation, distributed along the north side of the Bay of Fundy, indicated a Millstone-grit age. The discovery, however, by Mr. C. R. Matthew of the presence of a considerable area of micaceous slates, which are probably Devonian, in the very heart of the Grand Lake coal field, was very important, since it confirmed the view as to the apparent thinness of the measures at this point; while the fossils in the overlying rocks were of the horizon of the Millstone-grit.

The report of Professor H. Y. Hind to the New Brunswick government, (1865) contains a large amount of very valuable and interesting matter, relating not only to the geology, but to the mineral and agricultural resources of the province. A marked advance in geological knowledge is evident in connexion with the work, more especially in regard to the northern portion, concerning which area our information up to that time, owing to its largely inaccessible character, was very limited. A number of sections were made by Professor Hind along the various streams of the interior. The southern outline of the Upper Silurian was more clearly defined, both along the coast of Chaleur bay and on the Upsalquitch and Tobique rivers, as well as on the St. John, to the west. The great belt of metamorphic rocks of the interior, crossed by Professor Bailey on the Nipisiguit, was examined and classed by Professor Hind, principally on lithological grounds as the equivalent of the Quebec group of Canada, as laid down by the late Sir William Logan. The great areas of granite and syenite, both of the southern and northern portions of the province, were held to be intrusive and of Devonian age. No specially new facts bearing on the geology of the southern part of the province were advanced; the views of Bailey and Matthew in regard to the Devonian age of the metamorphic rocks of Albert and Kings being assented to. In the western area, however, the partly metamorphic belt underlying the Carboniferous basin on its northwestern side, and containing the antimony ores of Prince William,—rocks which had been regarded by Drs. Robb and Gesner as Cambrian, and by Matthew (see Appendix D, Report 1865,) as Lower

Silurian—was also classed by Hind in his Quebec group, and paralleled with the upper and slaty members seen on the Nipisiguit and other rivers in the northern part of the province.

On the lower Restigouche, between Campbellton and Dalhousie, Devonian rocks were recognized, skirting the shores, and associated with traps which present conspicuous hill features in this locality. Small outliers of Carboniferous conglomerate, near Dalhousie station, were also indicated, and their horizon was stated, in contradistinction to the early views of Dr. Gesner, who had regarded them as of the age of the Carboniferous and New Red Sandstone.

Following the report of Professor Hind the next contribution of note to the geology of the province was contained in the second edition of the *Acadian Geology,* 1868. The observations there given were based largely on the work of Dr. Robb, Professor Bailey, and Dr. Matthew. A large amount of additional information, relating principally to palæontological details, was also given, embracing the various formations from the St. John or 'Acadian group,' to the Carboniferous, both inclusive. The general distribution of the Laurentian and Huronian, the latter of which was still confined to the Coldbrook group, remained the same as in Professor Bailey's report, 1865. In the metamorphic rocks which surrounded the central Carboniferous basin, regarded as Lower Silurian, was included a large area in northern Charlotte county, and in the southern part of Sunbury and Queens, which was afterwards found to be of much more recent age. Following the determinations of Dr. Matthew the belt extending diagonally through the province from its southwest angle to the vicinity of Bathurst was also regarded as Lower Silurian, and not far removed in age from the St. John group. New and valuable matter relating to the Upper Silurian of Dalhousie and vicinity, with lists of characteristic fossils, was given, while to the same horizon was referred the Kingston group of the southern part of the province, which was also again paralleled with the Cobequid series of Nova Scotia. The accompanying map contained much new information, indicating a marked increase in our general knowledge of the structure of this interesting field.

In consequence of the passage of the Confederation Act in 1867, New Brunswick, at that date, came to a certain extent under the control of the Federal Government; and, in the ensuing year, the operations of the Geological Survey of Canada, which had been carried on continuously in Ontario and Quebec since 1843, were now extended to the Maritime provinces. In pursuance of this arrangement, Mr. C. Robb was sent to New Brunswick, to study more closely the structure of the country to the west and north of Fredericton, and along the upper St. John river, while Professor Bailey and Dr.

Matthew were assigned work in the southern part of the province. The results of these explorations appeared in two reports by Mr. Robb, in 1869 and 1870, and in a voluminous and exhaustive report by Messrs. Bailey and Matthew in 1871, reviewing the geological history of southern New Brunswick up to that date. This report, which evinces a great amount of painstaking research, has ever since been regarded as a standard work on the geology of this section, although modified in some respects as regards details of structure by later and more systematic explorations.

The first report by Mr. Robb made no attempt, in so far as related to the formations underlying the Carboniferous system, to decide the actual horizons of the rocks described, with the exception of the more northerly area, already regarded as Upper Silurian. The great metamorphic belt, regarded first as Cambrian and later as Lower Silurian, was divided into two parts, separated by the central granitic area. Their mineralogical and lithological characters were carefully given, and the discovery at one point on a branch of the Nashwaak river of a band of ochreous slates, holding fossils of Devonian age apparently intercalated with the metamorphic rocks, led to the supposition that this great formation might be newer than had hitherto been supposed. That the two bands to the north as well as to the south of the granite belt were of the same age was considered probable. The characters of the great central axis of granite were well described, and the highly altered condition of the various strata in contact with it was pointed out, the rocks in places having assumed a gneissoid structure and containing numerous crystals of staurolite, mica, &c. The extension of the metamorphic belt to the northeast beyond the Little Southwest Miramichi river was established, though fossils which might determine their actual age could not at that time be found.

Though no new facts tending to determine more precisely the position of these various groups in the geological scale were adduced in these reports, the large amount of topographical work done enabled Mr. Robb to construct a map of the three counties of York, Carleton and Victoria, upon which his observations of the two seasons were laid down. This resulted in a very great advance over the knowledge already possessed of that region, though the entirely unsettled character of the country east of the upper St. John prevented the accurate delineation of the several outlines of newer rocks, which occur at various points unconformably overlying the metamorphic series.

In the report by Professor Bailey and Dr. Matthew, which embraced a detailed account of the structure of the southern part of the province, the so-called Laurentian was divided into two portions, the lower of which consisted largely of gneiss and syenite of greenish, grey and reddish colours with associated masses of diorite. The total thickness of this division was not definitely known. The upper was largely a calcareous series, resting upon the lower at many points, and was made up of crystalline limestone, quartzite and slate, and with limited beds of gneiss. The actual thickness of this division was also somewhat conjectural, but a section on the St. John river, near Indiantown, one of the suburbs of St. John city, gave 1,385 feet, while the lower portion, omitting a considerable thickness of granitoid gneiss, recognized in the western part of the county of St. John, but not seen in the river section, was estimated at 2,850 feet. This would give, for the whole of the supposed Laurention rocks in this area, a probable thickness of over 5,000 feet. In a series of rocks, however, so extensively faulted and displaced as many of those in the vicinity of St. John, the actual measurement of their thickness is almost an impossibility.

Assisted by the extensive experience of Dr. T. S. Hunt, at that time an officer of the Geological Survey of Canada, the New Brunswick geologists then proceeded to attack the intricate problem of the metamorphic rocks, which, owing to their complex stratigraphy, had never been satisfactorily arranged.

Upon a more detailed examination it was conclusively established that rocks of Primordial age were, at several points east of St. John, unconformably placed upon what had so far been regarded as an integral position of the Devonian system, while the lithological characters of the latter presented many points of resemblance to those now recognized as of Huronian age. These discoveries, together with the fact that these supposed Devonian rocks were the possible continuation of the Coldbrook or Huronian belt of St. John and vicinity, led to their entire removal from the position they had so long held, on grounds both of stratigraphy and lithology, and to their being placed in the Huronian system, under the title of the Coastal group.

The importance of lithological characters being now recognized in the determination of certain horizons, especially when applied to areas of limited extent, attention was next directed to another great belt of metamorphic rocks which, under the title of the Kingston group, had, up to this time, been regarded as of possibly Upper Silurian age. This position had been assigned it on very much the same grounds that had affected the earlier position of the Coastal, viz., the supposed interstratification of its equivalents with fossiliferous Upper Silurian sediments which had been observed in eastern Maine. Subsequent examinations, however, proved the stratigraphical relations of the Kingston group to be entirely different. It was found at several points to underlie areas of primordial slates and, therefore, of necessity, to belong to a much lower position than had been supposed. At the same time the marked resemblance of the various rocks which composed the group to those of the Coastal and Coldbrook divisions was such that it was deemed most in accordance with the evidence at hand to include it also in the Huronian system. Thus, three great areas of metamorphic rocks, all presumably newer than Laurentian, had been established, though their relative positions to each other had not as yet been clearly defined. The Coldbrook group had, however, been divided into two portions, a supposed lower, including diorites with felsitic and chloritic rocks, largely a volcanic series, and an upper, consisting of argillites, sandstones and conglomerates, generally of reddish colours, which was considered to constitute the lowest member of the St. John group, since styled 'Etcheminian' by Dr. G. F. Matthew.

Since the arrangement of the formations, as given in the report now under discussion (1870-71), has been made to a large extent the groundwork of the subsequent publications on the geology of southern New Brunswick, the consideration of the groups newer than the Huronian may here be profitably taken up. Of these, the first in ascending order is the Primordial Silurian, Acadian, or St. John group, which latter name it received when regarded as an integral portion of the Devonian system, from the fact of its being largely developed and first studied in and near the city of St. John. By the fortunate recognition of its contained fossils in 1863-64, Professor Hartt, as already stated, first established the position of certain doubtful metamorphic rocks as Pre-Cambrian, and thus afforded a satisfactory basis for future geological work. Six areas were now recognized as probably belonging to the Primordial horizon; concerning the most of which no doubt could be entertained, viz.,—

1. St. John and vicinity, with its extension eastward for nearly thirty miles along the valley of the Loch Lomond lakes until it reaches the Hammond river.

2. Limited outcrops about the lower part of Kennebecasis bay, seen on Long and Kennebecasis islands, and on Milkish head, as well as on the south shore of the bay itself.

3. The valley of the Long reach of the St. John river. In these three areas typical fossils are abundant.

4. An area of dark grey and black shales in Wickham, Queens county, resembling in lithological characters the rocks of the previous divisions, but in which no fossils could be detected.

5. A similar series of beds in the valley of the Nerepis river, likewise apparently devoid of organic remains.

6. An area in Charlotte county, near the head of Oak bay. Other areas of supposed Primordial age have, however, since been found.

In all these the lithological characters are very similar, but later explorations on the areas in question led, in subsequent reports, to the separation of divisions 4, 5 and 6, on the grounds of lack of fossil evidence, and they were placed in a newly erected group of doubtful beds, under the name Cambro-Silurian. The true relations of these beds to underlying rocks of Pre-Silurian aspect will be considered further on, when the general structure as at present understood, is discussed.

Next in order, among the many puzzling and doubtful formations discussed in this report, we may briefly glance at the Mascarene series.

This group of rocks, so-called from its recognized development along the shores of the Mascarene peninsula, on the east side of Passamaquoddy bay, comprises strata of very different character. Some of these very closely resemble Huronian rocks, such as diorites, fine-grained felsites, petrosilex, &c. They are intimately associated with, and, in places, apparently overlie a series of slates and sandstones containing fossil shells and remains of plants. Here then is presented a second problem, somewhat similar to that which so long remained unsolved near St. John. The intimate admixture of beds of such great diversity of character rendered the expression of any definite opinion as to the real age of this group exceedingly difficult, and it was accordingly described as an isolated series, without being assigned to any definite horizon. A re-examination was made in 1874, and in the report for that year it was stated to be of Upper Silurian age.

The parallelism of structure displayed in this group of rocks is so marked, when contrasted with the earlier apparent superposition of metamorphic Huronian strata on the Devonian, east of St. John, that the merits of the question may be here briefly stated.

The various strata exposed along this portion of the shore are arranged in five divisions; of which the lowest consists of hard, grey feldspathic slates and olive grey argillites, apparently non-fossiliferous, and having a thickness of about 400 feet.

Div. 2, in ascending order, comprises black and dark grey banded siliceous slates, with obscure plant remains, and with thin bands of conglomerate; thickness rather more than 600 feet.

Division 3 consists of grey sandy flags and slates with slate conglomerates, in all about 400 feet, the greater part of which contains fossil shells.

Div. 4, principally bright red and green slates, sometimes with a purple tinge, apparently without fossils; thickness 300 feet.

Div. 5, principally hard, red felsites, often porphyritic and of Huronian aspect; thickness unknown, probably over 300 feet.

The geological position assigned this series in report 1874-75, as a portion of the Upper Silurian, seems, from the characters of its various divisions, to be somewhat unsatisfactory. Thus, on page 88, it is stated that division 2, or its equivalent on Beaver harbour, contains plant stems, among which a *cyclopteris,* a *cordaite,* a *sphenopteris,* and the remains of ferns, were clearly recognized. The presence of these imparts a Devonian aspect to this portion; while the Upper Silurian fauna in the overlying beds would indicate an overturn or a line of fault at this point. Confirmatory evidence in this direction is afforded by bands of igneous rocks, which had for a long time been paralleled with the Coldbrook and Kingston groups, and it is very probable that, taking into consideration the crumpled character of the sediments of Beaver harbour, with the enfolding there of narrow belts of rocks holding Silurian fossils, we may have a similar condition of things in the Mascarene peninsula.

Ascending in the geological scale we find the outlines of the Upper Silurian considerably changed as compared with all previous reports. The separation of the Kingston group made a great reduction in its aggregate thickness. In Charlotte county the formation comprised several localities where characteristic fossils were found, such as the vicinity of Oak bay and the group of islands and promontories lying between Beaver harbour and the Western isles. Collections of these were made at various points, notably at Back bay on Frye island, and at Oak bay.

Farther east in Kings and Queens counties the fossiliferous areas east of the granite, and extending to the St. John river, were well defined. These were found to embrace slates, sandstones and conglomerates, with a considerable thickness of hard, quartzose beds, and occasionally felsites and diorites, the total thickness being regarded as about 5,700 feet.

Along the line between Kings and Queens counties these rocks were found to overlie unconformably a series of hard felsites and other rocks of Huronian aspect, which form prominent hill features in this area, the débris of which enter into the composition of the basal beds of the Silurian. The age of these strata in the vicinity of Beaver harbour, as determined by the fossils there obtained, is about that of the Niagara formation.

The Devonian system was, as contrasted with the report of 1865, also largely remodelled. The four divisions of Bloomsbury conglomerate, Dadoxylon sandstone, Cordaite shale and Mispec conglomerate, were retained, but the first was reduced by about 2,000 feet of trappean and other volcanic rocks which, from their character, were now referred to the Huronian system, while the Cordaite shales were reduced by the separation of the apparently upper and metamorphic portion, which was erected into the Coastal group as already described.

The total thickness of the four divisions of the Devonian was estimated at 7,500 feet, but as the area is somewhat affected by faults this estimate may not be actually correct, owing to possible repetitions of certain strata. It does not include also the beds of the Perry sandstone group which, upon the authority of Sir William Dawson, from the evidence of contained plants, had been assigned to this system as its upper member several years before, and had also, in the report of 1865, been so described by Professor Bailey, but subsequently separated on the grounds of want of conformity to the underlying Devonian of Point Lepreau, and from a supposed resemblance to certain recognized Lower Carboniferous sediments in the vicinity of the St. John river. Various publications have appeared concerning the fossils of this group, among which may be mentioned those by Sir William Dawson in Can. Nat., 1861, on Pre-Carb. flora of Maine, etc.; Flora of Dev. period, in N. E. America, Geol. Soc., 1862; Observations on Dev. plants of Maine, Gaspé, etc., Geol. Coc., 1863; Fossil plants of Dev. and Up. Sil. of Canada, Geol. Sur., 1871. From the evidence, therefore, of its contained plants, and from its marked resemblance to much of the Upper Devonian conglomerate of the Gaspé district, it seems highly probable that this group should also be assigned to the Devonian rather than to the Carboniferous system. Its distribution is limited. It occupies the greater part of the peninsula between the St. Croix river and Passamaquoddy bay, underlying the town of St. Andrews, with several adjacent islands, and occurs in patches at the mouth of the Magaguadavic river, and as a considerable area about the village of Lepreau and on the peninsula which terminates in the point of that name.

Recent work by Dr. David White of the United States Geological Survey, on the plants of the Perry group, as developed in the vicinity of Eastport in Maine, has shown that they contain a well defined Upper Devonian flora. Within the last two years the continuation of the conglomerates and associated sandstones of this formation has been traced eastward through the islands of Kennebecasis bay where they contain a similar Devonian flora. Thence they have been followed to the northeast along the Kennebecasis valley almost continuously into Albert county, but are in places concealed for short distances by the conglomerates and limestones of the Lower Carboniferous formation which are unconformably overlying. Near the centre of the Devonian basin, to the east of Courtney bay, a detached area of the Perry is found which overlies the other divisions of the Devonian system in this direction, so that at this place there is a continuous ascending series from the base or Bloomsbury division to the top or Perry, the upper part of which is seen on the north side of Kennebecasis island. The division known as the 'Albert shales' lies between the basal Perry conglomerate and the upper grey portion, and is thus a part of the Devonian series.

The Carboniferous system comprised three divisions, the Lower, Middle, and Upper, of which the first, having a thickness of several thousand feet, contained the limestones, gypsum, ores of manganese, and the peculiar mineral albertite, while the Middle and Upper were briefly described under the general term, Coal-measures, since the examination of this formation had not been carried on sufficiently to warrant a separation of its various members. The subdivisions of the Lower Carboniferous were, in the first edition of *Acadian Geology,* made to include the bituminous shales and associated conglomerates of the Albert mine, which were regarded as the lowest portion. This order of succession was, however, somewhat modified by Dr. Matthew from subsequent observations made along the line of railway near Norton, where the bituminous beds had an apparently higher position.

The distribution of the Lower Carboniferous series was given with considerable accuracy, and the presence of a volcanic, intercalated portion in a section along the St. John river, in the parish of Hampsted, was noted, trappean and feldspathic rocks occurring both near its summit and base. This volcanic feature is also well observed at other points, not only along the southwestern margin of the formation in Queens, Sunbury and York counties, but in outcrops at intervals in the very centre of the Middle Carboniferous basin about the upper end of Grand lake. As these rocks, however, had at this time not been particularly studied, many additional facts regarding them were brought to light on later investigations, and have been described in more recent publications.

The opinions stated in this report, 1870-71, regarding the Middle Carboniferous, confirmed those expressed by Dr. Robb in 1850, viz., that this formation was of no great thickness and was probably represented only by its lower member, as indicated by the presence of the outcrops of metamorphic slate, pointed out by C. R. Matthew, in what was supposed to be the thickest portion of the coal-field. The fossils collected were, for the most part, characteristic of the lower horizon, but in several cases appeared to indicate a higher range, embracing Upper Carboniferous forms, which it was supposed might be derived from unconformably overlying patches of newer rocks, or more probably from a mingling of the flora of different horizons.

The deposits along the Bay of Fundy, described as of Triassic age, have, as in the case of so many other formations, been long a subject of dispute. Dr. Gesner, in his early reports, included not only the areas mentioned in the report under consideration as probably of this age, but also other deposits, some of which, like those of Lepreau and Passamaquoddy bay, have been seen to be presumably Devonian, while others, farther east, are now known to belong to the Lower and Upper Carboniferous formations. Dr. Robb, on the other hand, held that no rocks newer than Carboniferous existed in New Brunswick.

In many respects the limited areas which occur as outliers on the coast of the Bay of Fundy referred to in this report resemble and are probably the equivalents of the so-called Triassic of Nova Scotia; while other areas of soft red rocks, in the eastern part of the province, are of Upper Carboniferous age and similar to those seen in Prince Edward Island. The supposition has been confirmed by recent investigation.

The presence of plant remains in the sandstones at Quaco and Martin head, similar in character to those found in Prince Edward Island in what was formerly there regarded as Lower Trias, but now held to belong rather to the Permian, makes it very probable that more detailed study of these rocks will show that they also may be classed as the upper member of the Palæozoic series. In their stratigraphical relations there is nothing to indicate their higher position, since they rest generally on Upper Devonian sediments, while the occurrence of undoubted Upper Carboniferous beds in Westmorland county, similarly placed, and closely resembling these in character, tends to support the present view.

Triassic sandstone and shales are seen at several points on the Bay of Fundy coast, as at Martin head, Salisbury bay, and between Red head and Gardner creek, the last about twenty miles east of St. John city. Where associated with igneous rocks they appear to rest upon them. The large development of trappean rocks seen on Grand Manan is supposed to be of Triassic age, the western part of that island being composed largely of basalts, amygdaloids, and trap ashes, with limited exposures of red sandstone, which, near the contact, are impregnated to some extent with copper glance, supposed at one time to constitute a deposit of economic value.

There yet remain to be considered two groups mentioned in the report for 1870-71, which, owing to their great diversity lithologically, have ever been difficult of adjustment in the geological record.

These were described under the head of various Pre-Carboniferous rocks, and were divided into two portions, styled, from their prevailing colours, the 'dark and the pale argillites.' The lower members, which were generally dark-grey and often flinty in texture, were highly feldspathic, and so far as could be ascertained, were generally devoid of fossils; the upper, while usually of a lighter hue, had a greater preponderance of grey sandstones and shales and in places showed indistinct traces of plant remains. The lower series is found often in direct contact with the great granitic mass of Charlotte and Kings counties, the metamorphic action of which was evidenced by the alteration of the clay slates into schists, and by the production of crystals of staurolite, actinolite, mict, etc., in the adjacent beds. No definite fossil evidence could be found to locate this group in the scale of formations, though from the resemblance of its lowest members to the lower portions of the Mascarene series, it was supposed to be not far removed from the horizon of the Upper Silurian. The similarity of much of the upper group to the portion of the Devonian characterized as the Cordaite, together with the presence of plant remains, and its stratigraphical position between the dark argillites and the Lower Carboniferous, caused this portion to be regarded as probably belonging to the Devonian system. Both these series were, in the map accompanying the second edition of *Acadian Geology*, coloured as of Lower Silurian age.

Subsequently, in 1875, these Pre-Carboniferous rocks were arranged by Dr. G. F. Matthew under three heads, viz., Huronian, Upper Silurian and Devonian, with the proviso, however, that some portions, notably of the dark argillites, or lower group, presented strong resemblances to the Lower Silurian of the western part of the province. But later, in the general report accompanying the map of southern New Brunswick, (1878-79) they were re-arranged, the pale argillites being placed permanently in the Devonian, the doubtful or dark argillites classed as a new group, under the title of Cambro-Silurian, while a large area to the east of and between the granite ridge and the St. John river, in which typical fossils were found at various points, was called Silurian, certain areas of felsites which protruded through these fossiliferous sediments and formed prominent hills and ridges being, from their lithological aspect, regarded as Huronian rocks.

Resuming the regular history of New Brunswick geology, the next paper on the subject was by Professor L. W. Bailey, 1871-72. This dealt principally with the extension eastward of the Huronian system into Albert and Kings counties, more particularly with reference to the Coastal group, which was found to occupy the greater part of the country bordering on the Bay of Fundy in this direction, and was regarded as constituting the mineral bearing, or copper belt of this area. Attention was also directed to the presence of a small deposit of supposed true coal-measure rocks at Dunsinane, on the railway between Sussex and Petitcodiac, (see also Report 1865, p. 157) which was thought might be similar in character to the coal area of Springhill, in Nova Scotia, a supposition, however, not verified by later examination of the district. The occurrence in eastern Albert of intrusive traps of supposed Triassic age was also noted, and this was considered important as tending to strengthen the view expressed the previous year as to the Mesozoic age of certain patches of red sandstone found at points along the coast in the vicinity. The intrusive character of the red granites, both of the great southern area in Charlotte county as well as certain masses in Albert and Kings, not only in Silurian sediments, but clearly intruded into older and possibly Laurentian rocks in the southwestern portion of the province, was well indicated.

The season of 1872 was devoted to an examination of the central or Grand Lake coal-field, with a view to determine more conclusively its economic value, by a series of borings, and thus to settle definitely the much vexed question as to the occurrence of workable seams underlying that, which, as a surface seam, had been worked to some extent for many years. No detailed study of this coal-field had been attempted since the time of Dr. Robb, whose views on the subject have already been stated. In the report on this area, 1872-73, the entire thickness of the formation above the Lower Carboniferous was estimated to be only 600 feet, which was divided into three portions of 200 feet each, assigned to the Millstone-grit, the Productive Coal measures, and the Upper Carboniferous, respectively. The general thinness of the formation was again conclusively shown by the presence of areas of older rocks at various places at and near the surface, and subsequently by means of the diamond drill, which penetrated the entire thickness of the Middle Carboniferous at the head of Grand lake, at a depth of little more than 200 feet. Borings carried on during the next three years, at different points, effectually proved the generally barren character of the measures, and disproved beyond a doubt the erroneous ideas entertained by many concerning the great economic importance of this area.

Later examinations of the Carboniferous basin over its entire extent, embracing an area of 10,000 to 12,000 square miles, have led to a modification of the views then expressed, and it has been satisfactorily established that with the exception of certain small outlying patches of Upper Carboniferous rocks, occurring for the most part along the shore of Northumberland strait and in the eastern part of Westmorland county, the rocks of the entire area belonged to the horizon of the Millstone-grit, and were below the true productive measures of Nova Scotia.

The season of 1873 was devoted to the completion of the geological and topographical map of Queens and Sunbury counties, embracing not only the coal-field just described but the various formations bordering this area on the south, including the hitherto doubtful groups of the argillite series and the associated strata, supposed to be of Huronian age. The conclusions then arrived at, together with the map, were withheld for several years, pending further investigations, or until the appearance of the general geological map of southern New Brunswick in 1878-79, in which, however, the views expressed were very considerably modified as compared with those held in 1873.

In 1874-75 several papers on he geology of the province were published. In Charlotte county these related more particularly to the Mascarene series as developed about Passamaquoddy bay, and in the adjacent part of the State of Maine. From the facts then observed the age of the series was inferred to be Upper Silurian, but as this question has already been fully discussed in previous pages nothing further need here be said. The age of the pale argillites was, from the observations of the preceding season, proved to be, for the most part at least, Devonian while, concerning the lower or dark argillite group, satisfactory conclusions could not be arrived at.

Other papers appeared relative to the age and distribution of the iron ore deposits of Carleton county (R. W. Ells, 1874) and sundry facts were also given concerning the structure of the Grand Lake coal-field, derived from boring operations, by which the statements already made respecting the general barrenness of the measures were fully confirmed.

In this year, also, (1874) appeared a paper by Dr. Honeyman of Halifax, Nova Scotia, upon the various formations of the southern and eastern portions of New Brunswick, in which he paralleled the supposed Laurentian and Huronian systems about St. John, with the rocks of the Cobequid series in the adjoining province, and with his lower Arisaig group of Antigonish. In the northern part of the province he regarded the fossiliferous limestones of Dalhousie as probably of Niagara age, (the equivalents of his group, C. Arisaig) and recognized also the Lower Silurian, now Cambro-Silurian, aspect of the rocks on the lower Nipisiguit and Tetagouche rivers, in which graptolites were afterwards found, presumably of the horizon of Lower Trenton age, while the later age of the intrusive traps in the Dalhousie section, first pointed out by the late Sir Wm. Logan, was proved by the alteration of the contiguous beds and by the presence of Upper Silurian fossils contained in the trappean mass itself.

In 1875-76, a report on the Pre-Carboniferous formations of southern Queens and Sunbury counties, with various rocks in northern Kings, was presented, illustrative largely of the work done in 1873. These were now divided into three groups, the crystalline or older felsitic series, Coldbrook or Huronian, the dark argillites which were now considered to be Upper Silurian, though possibly containing areas of Lower Silurian, and the pale argillites, which were again asserted to be Devonian, from the evidence of the contained plant remains. The Upper Silurian, however, was now made to contain a considerable area of what was in 1870-71 regarded on lithological grounds as Pre-Silurian or Huronian.

In 1876-77 an interesting report by Dr. G. F. Matthew on the geology of Charlotte county was published. In this the aspect of certain supposed Pre-Silurian rocks in the southwestern portion was discussed, more especially in their development west of the lower part of the Digdeguash river. These, for the most part, highly crystalline rocks, consist of diorites, fine and coarse, hard schists, porphyritic and slaty felsites and gneissoid sandstone, which often present the appearance of fine-grained gneiss. They form an area of considerable extent and are intersected by intrusive granites which may be spurs from the main granitic mass of that district. They cross Oak bay and extend into Maine, and also form a conspicuous band on the St. Croix river, in the vicinity of, and for some distance above, St. Stephen and Calais. The fact that these volcanic rocks penetrate recognized Silurian strata in that vicinity was not apparently recognized at the time, and from their marked lithological resemblance to the Pre-Cambrian of St. John county they were regarded as also of Huronian or Laurentian age.

In this report, also, the dark argillites which have a considerable development in this country, forming an extensive belt which stretches diagonally across from the St. Croix river to its northeast corner, were considered as of Upper Silurian age. The rocks of this system were arranged in five divisions, the three lowest being paralleled with the divisions of that system, as stated in the report for the preceding year, whilst Nos. 4 and 5 of that series were supposed to represent Nos. 3 and 4 of the Kingston group. The latter was, by this arrangement, removed from the position assigned it in 1870-71 as a portion of the Huronian, to the upper part of the Upper Silurian, chiefly from its supposed superposition on the St. John group, as inferred from the presence of pebbles of black slate in the conglomerates near its base, which were held to be derived from beds of Primordial age.

The crystalline and Huronian aspect of the Kingston group, as a whole, can be well seen by reference to the sections given in New river, Charlotte county; the character of the several divisions there seen being as follows:—

Green chloritic and granitoid rocks.

Dark, porphyritic, slaty felsite, with grains of clear quartz.

Grey clay-slates and diorites.

Chloritic and feldspathic slates and grits, with slate conglomerate overlaid by about 11,000 feet, principally schists both micaceous and hornblendic, the latter predominating, crystalline felsites, and capped by chloritic and feldspathic gneiss.

No fossils were found in any of the strata, but it was distinctly stated that this group in Charlotte county constituted the mineral belt in the same way as the Coastal group to the eastward, which was also formerly considered to occupy nearly the same relative position as now assigned to the rocks under discussion. As, however, uncertainty still existed as to the true position of the Kingston group, the publication of the map and section accompanying this report was for the time deferred.

In the report for 1876-77 the relations of the great mass of red syenite and granite which forms so important a feature in the geology of this county, to the associated rocks, were also given. That they were clearly newer than the overlying Upper Silurian was evidenced by the metamorphism of the slates in contact, shown by the production of various crystals, as also by the presence of numerous faults and dislocations, and by the penetration of contiguous strata by numerous dikes and veins of granite, which, proceeding from the main mass, cut the adjoining beds with sharply defined lines of contact.

The same volume also contained a report on the Lower Carboniferous of Albert and part of Westmorland counties, by Professor L. W. Bailey and the author of this paper. This had particular reference to the distribution and economic value of the portion known as the Albert or bituminous shales, of special interest from their containing the remarkable mineral, albertite. In this paper, also, the Pre-Cambrian aspect of the rocks of the Caledonia Mountain range was pointed out. The divisions of the Lower Carboniferous there given were five in number, representing an exposed thickness of 4,150 feet, separable into two unconformable series by a break between the bituminous shales and associated conglomerates of the Albert Shale series and the sandstones and conglomerates of division 3, while the great masses of gypsum and limestone were regarded as being near the upper part of the formation.

The season of 1877-78 was devoted to further detailed work, principally bearing on the relative positions of the various divisions of Pre-Silurian rocks in Kings, St. John and Albert counties, the results of which were stated in three papers by the writer, Professor Bailey, and Dr. G. F. Matthew respectively, with a supplementary report by the last on the superficial geology of the southern part of the province.

In the first of these, the structure of the Pre-Cambrian ridges was given as follows:—three main anticlines, situated to the south of Kennebecasis bay, extend from the vicinity of St. John north-easterly, and are roughly parallel to the north shore of the Bay of Fundy. In Albert county, and for some distance to the west, the two more southerly anticlines are apparently overturned; the contained syncline occupying the area along the Shepody road, and for some distance on either side. The most southerly anticline forms the crest of the mountain ridge in rear of Hopewell, whence, extending westerly, it crosses the Upper Salmon river some three miles below the Shepody road, and comes to the coast a short distance west of Martin head. On the Albert county-line it has a breadth of three to four miles, and is distinguished by the presence of syenite and gneiss, often greenish or protogine, with schists, felsites and dolomites,

The second anticline extends from the eastern part of the Caledonia Mountain range in the vicinity of the Albert mines, southerly through the southern part of Mechanic settlement, and reaches the Shepody road a short distance west of the Kings county line, on which road it can be traced for nearly eight miles. Farther west it can be seen on the Big Salmon river, about four miles from its mouth, beyond which it is apparently concealed by overlying sediments. This anticline in Albert county is flanked at one point by crystalline limestones, similar in character to those in the vicinity of St. John.

The third anticline comprises the syenite, gneiss and limestone of St. John and vicinity. Westward, it can be readily traced to its termination on the coast at Musquash harbour, although in places concealed by Devonian strata and drift deposits, while eastward it extends along the south side of Kennebecasis bay, appearing also in the islands and headlands of the southern extremity of the Kingston peninsula, uninterruptedly to a point about four miles south of Hampton station. It re-appears from beneath Upper Devonian beds, four miles farther east, and forms a narrow ridge, eight miles in length, when it again becomes overlapped by the Perry formation, and does not re-appear, but on the Kings county line an anticline, in the continuation of the one just described, brings up the Perry conglomerate and grey sandstone and probably indicates the extension of this third axis which in this case is parallel with the second anticline of the Caledonia mountain.

A series of chloritic, talcose and feldspathic schists, ash rocks, purple grits, and conglomerates occupy the first syncline in Albert county. These are apparently unconformable to the rocks of the underlying anticlines just described, as well as to their supposed equivalents in Kings and St. John counties. They occupy a considerable area along the Shepody road, and the greater part of the coast of the Bay of Fundy, between Point Wolf and Melvin beach, about seven miles east of Quaco.

Along the northern side of the second anticline in Kings county these rocks, which constitute the Coastal portion of the Huronian, are to a great extent apparently replaced by a considerable thickness of brecciated, siliceous and feldspathic ash rocks and diorites, which, according to Professor Bailey (see his report on this group, 1877), compose the greater part of the Pre-Cambrian series to the south of the main Laurentian axis or anticline No. 3. These are regarded by him as older than the Coastal rocks which occupy the syncline just mentioned and which form the shore series. They are described in ascending order under two heads, the first or felsite petrosilex group consisting largely of the following rocks:—

Red and grey felsites, blue, grey, reddish and black petrosilex and breccias, diorites, and amygdaloidal ash rocks and ashy conglomerates.

Grey feldspathic sandstones and conglomerates, the whole representing the Coldbrook of former reports and now regarded as the oldest member of the Huronian.

The second or upper division consists of the following rocks:—

Chloritic schists, greenish, grey and purple ash rocks and amygdaloids, with purple conglomerates.

Pale grey pyritous and rusty-weathering felsites and feldspathic quartzites.

Hydromica schists, chloritic and feldspathic schists, grey clay-slates and purple conglomerates, with beds of hematite, styled Coastal in former reports, and now regarded by him as the upper member of the Huronian.

The third report, by Dr. G. F. Matthew, is confined to the Kingston group and principally to its development in the Kingston peninsula, where from the discovery of a small outcrop of fossiliferous ashy rocks and slates of Upper Silurian age along the south side of the Long reach of the St. John river, which at several points on the shore appear to have a dip inland, it was inferred that a large portion of the rocks of this group were stratigraphically above the fossiliferous beds and consequently newer. He, however, at the same time, in tabular form, paralleled the Kingston of this locality and its extension westward into Charlotte county, under the heading Upper Silurian, with the recognized Huronian of St. John, in which the lithological resemblance of the two groups is such as to strike the most casual observer.

The Huronian character of the crystalline and metamorphic rocks of southern New Brunswick was next pointed out by Dr. T. Sterry Hunt, in his report to the Geological Survey of Pennsylvania, published in 1878, and subsequently in a paper read before the American Association for the Advancement of Science, (1879), in which the unconformity of these rocks to the supposed Laurentian of the St. John area was indicated, as well as their lack of conformity to the overlying Primordial slates. In the Supplement to *Acadian Geology,* (Sir Wm. Dawson, 1878) several allusions to this province also were made, the principal points of which have been already considered. In this year, too, the final report on the geology of southern New Brunswick appeared, accompanying the map of that area, which had been so long deferred. From a careful consideration of all the data in the possession of its several authors, which had been accumulating for years, the various geological lines were there laid down, and the most recent and probable views concerning the horizons of the different formations stated. As no subsequent publication on a large part of this portion of the province has since appeared, the position and arrangement of the geological systems as there expressed may be briefly stated, with some probable changes which may hereafter be made in certain groups, about which sufficient was not at that time known to pronounce definitely as to their exact age and relations.

It must be premised that in speaking of the geology of southern New Brunswick, that portion only is included which lies to the south of the great central Carboniferous area, in so far as relates to the Pre-Carboniferous rocks. The study of the northern and southeastern portions having been taken up at a date subsequent to 1878, these areas will be considered further on.

The geological systems recognized at that date (1878-79), in that portion of the province now under consideration, are as follows:—

Laurentian	Lower. Upper.
Huronian	Formerly divided into Coldbrook, Coastal and Kingston.
Cambrian	Primordial Silurian, Acadian, or St. John group.
Cambro-Silurian	Formerly Middle Silurian.

Silurian.	
Devonian.	
Carboniferous.......	Lower.
	Middle or Millstone-grit.
	Upper of eastern Westmorland county.
Triassic.	
Intrusive rocks......	Granites, syenites, diorites, diabases. Trappean rocks of Carboniferous and Triassic age.[*]

In the general geological map of the southern part of the province, 1878-79, the area coloured as Laurentian embraces principally that portion which, in 1860, was separated from the Devonian, under the title of the Portland group. West of St. John city it embraces the greater part of the county of St. John, extending across into Charlotte county, and terminates westward at Ragged head, which forms the southwestern point of Lepreau harbour. Though apparently divisible into two unconformable series it was not deemed advisable to colour these separately, but the limestones were designated, wherever known to occur, by a distinct tint, and thus the upper member was, to a certain extent, made conspicuous.

The anticlinal structure of the lower member was regarded as well marked, and its probable extension northeasterly has already been given. The limestones in the vicinity of the St. John river flank the axis on either side. These are well developed along the south side of Kennebecasis bay, and from South bay they extend at intervals for about four miles west of the river, where they apparently form a basin. Eastward they appear as outliers on the syenitic rocks beyond Rothesay, and at several points as far east as Norton. West of St. John they appear at Pisarinco and at Musquash harbour on the south flank of the main anticline. The width of this supposed Laurentian area, comprising both divisions, is from six to seven miles.

In report 1870-71 it was stated that a belt of gneissic rocks, bearing much resemblance to those just described, extended from the head of the Long reach of the St. John river, along the north side of that sheet of water, to L'Etang harbour, forming an anticlinal ridge flanked by supposed Huronian sediments. On Frye island, near the southwestern extremity of this axis, syenitic rocks occur with crystalline limestone, in character somewhat similar to those which occur with so-called Laurentian rocks elsewhere, and the whole belt was considered as probably a parallel ridge, contemporaneous with the belt just described. While, however, this view was held concerning the age of these rocks, the difficulty of separating them precisely from the overlying Kingston group, owing in large part to the wooded character of the country which they traverse, was such that it was thought best to include this series in the general Pre-Cambrian colour without definitely specifying its exact position. Lying off the coast in this direction the group of islands called The Wolves was found to be composed of greenish syenites and other rocks of the lower series in which, however, no limestones appeared.

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[*] NOTE.—The conclusions arrived at and stated in this report may be briefly summarized. Recent investigations in the southern part of the province, from the St. Croix river on the west to the Black river east of the city of St. John, have caused these opinions to be largely modified, and the recent changes will be also indicated.

Farther west in the parishes of St. Patrick, St. Croix and St. Stephen, syenitic, dioritic and gneissic rocks are common. These in the vicinity of the St. Croix river present characters very similar to those of the fundamental rocks of the St. John area, and were at one time described as of the same horizon. They are intersected by large dikes and masses of intrusive syenite, some of which are of much later age than the rocks with which they are associated. In this locality, also, the authors found much difficulty in separating the newer intrusive rocks from the older portions, and all these areas of syenites, etc., of whatever age, were therefore included in the same colour, though the outlines of the newer are indicated on the map in a general way.

It must therefore be fully understood that in the area indicated as granite, west of the Digdeguash river, and for a mile or so to the east, a considerable portion might possibly be of Pre-Cambrian age.

In Albert county, also, attention was called in 1870-71 to the presence of rocks similar to those of the so-called Laurentian of St. John, and the supposition was then advanced that these occurred as ridges surrounded by Huronian strata. This view, in so far as the stratigraphical relations of the several groups were concerned, was confirmed in 1878, and the probable Laurentian age was indicated by the presence of crystalline limestones and dolomites. The older portions of these ridges, as we proceed westward into Kings county, speedily become concealed by the unconformable overlap of the Coldbrook and Coastal groups, from which, in lithological character, they are markedly different. They contain also a considerable area of coarsely crystalline diorites, holding magnetite, which in places become almost a pure hornblende rock.

A similar area of magnetic diorite in northern Kings county near the Scottish settlement was referred to in 1870-71, and was supposed to be of Laurentian age, as were several areas west of the St. John river, in the valley of the Nerepis. The dioritic rocks in Charlotte county, near St. Stephen, are also probably of this age. They contain serpentine and chromic iron in small quantity and were supposed to underlie, unconformably, hard micaceous quartzites. East of St. John, near Dolin lake, bands of hard crystalline, feldspathic, sometimes dioritic, rock occur, associated with hypersthene and magnetic iron, which were considered by Dr. T. S. Hunt as identical with some varieties of norite rock of the Upper Laurentian or Labradorian series. They are associated with gneisses, also presumably of the upper division.

The limestones near St. John are in places serpentinous and have furnished indications of the presence of *Eozoon* structure. At Pisarinco, also, serpentine is found in talcose and chloritic rocks, associated with limestones, and at the falls of the St. John river deposits of plumbago of large extent are found in the slates and limestones. It is worthy of remark that in all the supposed Laurentian areas of Charlotte county no traces of limestone have as yet been found, except at Frye island and Lepreau.

The work of the last three years in Charlotte and St. John counties has caused a marked modification of the views formerly held as to Laurentian rocks of southern New Brunswick. Thus, as regards much of the granite, gabbro, diorite, and diabase it has been shown that the greater part at least of these are of comparatively recent date; that they are clearly intrusive through Silurian and sometimes Devonian sediments; that the crystalline limestone of Frye island is altered Silurian instead of Laurentian, the metamorphism being due in part to pressure and in part to large masses of intrusive rocks; that the crystalline limestones of Lepreau harbour and of Musquash village are altered portions of the Devonian (Bloomsbury), and that the crystalline limestones of St. John county, as seen on the east side of Musquash harbour and along the shore east of Pisarinco, are also locally altered and cut in all directions by masses and dikes of granite and diabase, which also cut the Bloomsbury division of the Devonian and other parts of that series of formations; that the crystalline limestones of St. John city and vicinity are not a part of the Laurentian formation (Grenville series of Quebec) but are associated with highly altered banded slates and quartzite which are similar in character (though sometimes more highly altered) to the lower portion of the Cambrian rocks of that city though as yet they have not yielded fossils; that the series of gabbros, granite and diabase rocks which were once regarded as representing the Lower Laurentian or Fundamental gneiss are in reality intrusive igneous rocks of later date than the slates and limestone with which they are now associated; and that a very close examination of these so-called oldest rocks could not determine any rocks of Laurentian age in the southern part of the province, at least at any observed point.

The history of the Huronian system, with the many changes which have taken place in relation to its various groups, has already been somewhat fully stated, and we will, therefore, here present only the views held in 1878-79 regarding its distribution and mineral character.

The term Huronian does not appear on the general map, for the reason that, owing to the uncertainty as to the age of the several groups, some of which have just been described, it was thought best, until their true relations to the Laurentian or Huronian systems proper could be accurately worked out, to include these under a general term, Pre-Cambrian, since, in position, they were found to unconformably underlie at several points the fossiliferous Cambrian.

The former division of the Huronian into Coldbrook, Coastal and Kingston was exceedingly unsatisfactory, inasmuch as while they were all regarded as portions of the same system, their respective horizons could not with certainty be determined. Thus, in 1870-71, the Coldbrook is the first described after the Laurentian, leading to the inference that this group comprised the lowest members of the Huronian system, while at the same time its upper part was held to represent the basal beds of the St. John group, to the exclusion of the Coastal and Kingston. In the last report by Professor Bailey (1877-78) the Huronian south of the Kennebecasis was divided into two groups only, the Coldbrook and Coastal, of which the latter is held to be the newer. The older is distinguished by the term 'felsite petrosilex group,' from the prevailing character of the rocks which compose it, while the newer is termed the 'micaceous and chloritic' or 'schistose group,' for the same reason. It is evident, from a consideration of the rocks of the Coldbrook, that they are for the most part of volcanic origin, the prevalence of breccias and brecciated agglomerates, diorites and ashy rocks, which make up the bulk of the group, presenting a marked contrast to the more slaty and schistose rocks of the Coastal, though the latter shows abundant evidence also of volcanic action in the presence of ashy and agglomerate rocks; it has also a considerable thickness of clay-slates, with purple grits and conglomerates. It is exceedingly doubtful, however, whether a separation such as has just been proposed, into an upper and a lower division, can be successfully made on stratigraphical grounds, owing to the difficulty of determining which group rests primarily on the supposed Laurentian, since in some places this position is held by the Coldbrook, while at others the Coastal is in direct contact. This difficulty becomes more apparent when we consider that the original Coldbrook, so named from the place where first studied, was at a later date regarded as Coastal. It is possible that both divisions may be contemporaneous, or that the Coldbrook or volcanic portion may be the more recent; this latter view receives a certain amount of support from the stratigraphical evidence seen in the overturned syncline of Albert county, the rocks of which rest upon the basal ridges and are undoubtedly of the Coastal or schistose type, (see Rep. 1877-78). These occupy the southern portions of eastern Kings and St. John counties, and, while in their western extension they overlap the ridges just mentioned, they are in turn apparently overlaid by the volcanic rocks of the Coldbrook group, the Coastal not appearing at all in the northern portion of the main Pre-Cambrian area south of the Kennebecasis, unless we except certain doubtful and limited areas lying to the north and east of the Loch Lomond lakes.

There yet remains to be considered the third division of Huronian rocks, the Kingston group, which, also receiving its name from the place where first studied, namely, the peninsula lying between the Long reach and Kennebecasis bay, has a considerable development westward in Charlotte county. The various changes of opinion respecting the position of this group have already been stated, and we will, therefore, give the reasons, lithological as well as stratigraphical, which seem to us conclusively to prove that a portion of these rocks should be considered an integral part of the Huronian system. The character of the rocks which compose this group is well given in the report of Dr. Matthew, already referred to, for the Kingston area and for its extension westward, and is here presented for the sake of comparison:—

Compact, dark-grey diorite, and fine-grained, flesh-red felsite.

Hornblende and mica-schists, schistose diorite, and dark feldspathic slates, with grey argillites.

Fine-grained mica-schist, silico-feldspathic gneiss and schistose felsite. Chloritic gneiss and syenite, with thin beds of limestone, argillites, etc.

In addition, beds of slate conglomerate occur, and chlorite and epidote are found in veins of considerable size.

That the Kingston group is in part at least entirely distinct from and older than the Silurian was pointed out in 1870-71; but the Pre-Cambrian aspect is more clearly indicated if we glance at its structure as seen along the St. John river. By reference to the general report, 1878-79, it will be seen that the Pre-Cambrian rocks of southern New Brunswick are arranged in a series of approximately parallel anticlines, the synclines being occupied by fossiliferous Cambrian strata.

These anticlines were arranged in five divisions, of which Nos. 1 and 2 were considered of Laurentian age, No. 3, Coldbrook, No. 4, Coastal, and No. 5 Kingston.

This arrangement does not, however, necessarily indicate the true stratigraphical position of the various groups; for, while we have seen that the Coastal has not yet been definitely proved to be the upper portion of the Coldbrook, it is probable that the Kingston includes, in part at least, rocks common to both divisions 3 and 4, and possibly even lower.

The extension of the anticlines 1, 2 and 3 has already been given. Of the last two, which pertain to the Kingston peninsula, No. 4, beginning at Clifton on the south side, extends northeast past the head of Kingston creek, towards Dickie mountain, while No. 5, commencing near the western extremity, and well seen at Milkish creek, keeps along the north side of the peninsula, and crossing the entrance of Belleisle bay is probably continued along the north side of that sheet of water into the Scotch settlements.

A sixth ridge bounds the Long reach on the north and forms the eastern extremity of that which, in Charlotte county, on the north, was stated to underlie Huronian sediments, and to be possibly of Laurentian age.

That all these ridges are, at least, Pre-Cambrian, was held to be plainly indicated by the presence of unconformably overlying areas of Cambrian slates, which occur in the form of basins of greater or less extent, the limits of which have been largely affected by denudation.

The most northerly of these, definitely recognized by fossils, is found on the west flank of the sixth ridge; but along its south side a much more important belt occurs, which occupies the greater part of the north shore of the Long reach from the mouth of the Nerepis to Jones creek, beyond which it is largely concealed by Silurian beds. It also appears in several small islands in the river and on the point at the month of Belleisle bay, where it overlies the more northerly of the two Kingston anticlines. It is quite possible that this basin of Cambrian rocks occupies the entire valley of the St. John river at this place, although its contact with the Kingston group along the south side of the reach is partially concealed by fossiliferous strata, which are possibly the prolongation southward of the Silurian area of Jones creek, since the overlap of the Primordial on the Kingston rocks is well seen at both extremities of the basin. It is probable also that the horizon of the two ridges of metamorphic rocks which extend on either side of the Long reach is not very different; although westward of the St. John river the Kingston group proper appears to occupy a syncline between the Lepreau axis and the older ridge north of L'Etang. This position would also correspond, on stratigraphical grounds with that assigned to it from lithological characters as largely representing Divisions 3 and 4 of the Pre-Cambrian scale, but in this part of Charlotte county the Primordial has not yet been definitely recognized.

The presence of slaty conglomerates in the rocks of the Kingston group, the pebbles of which were at one time regarded as derived from Cambrian slates, has been recognized. The fragments may be derived from the bands of black and graphitic slates, which, at many points, form an integral portion of the rocks to the rear of St. John city and elsewhere.

In the areas coloured Cambro-Silurian, extending along the county line of Kings and Queens, belts of rock which very closely resemble those just described are found. They consist of hard felsites, often porphyritic, with felsitic, chloritic and talcose schist, and fine and coarse diorites. After many ineffectual attempts to separate these satisfactorily from other slaty beds, with which they are intimately associated, the greater part of these areas was included, provisionally, in the metamorphic Cambro-Silurian system. These areas of igneous rock are in no place of great extent, but appear as crests of ridges exposed by denudation and protruding through the overlying strata.

In fact, the greater part of the formations of southern New Brunswick have been so intricately folded that the problem of deciphering their exact age has been a very difficult one; and it is to be presumed that with the accession of new light, derived from the study of similar rocks elsewhere, other important changes will be found necessary.

The views concerning the geology of the islands called the Western isles, in Passamaquoddy bay, have undergone the same changes as already described in connexion with the Pre-Cambrian rocks farther east. The group of The Wolves, consisting almost entirely of syenitic and gneissoid rocks, is probably the western prolongation of similar rocks from the mainland at Lepreau; while Campobello and Deer islands, together with the greater number of the smaller islands lying between these and the shore, represent, probably, the extension of what has been styled the Kingston group. Ores of copper and iron are common, in which respect the rocks resemble those of the metamorphic Coastal belt east of St. John, as well as in their general lithological character.

Recent investigations in this area (1903) have shown that the rocks of the islands in Passamaquoddy bay and in parts of the main land adjacent to the north, as at Letite, Frye island and elsewhere, consist largely of altered Silurian sediments, closely associated with dikes and masses of later intrusives, mostly diabasic in character, which have locally altered the Silurian slates and limestones, though the contained fossils can be seen at several points, but are generally much distorted.

From 1878 to 1903 no detailed examination was made of the Huronian rocks of Southern New Brunswick. In 1903 some detailed work was done in Charlotte county and has since been extended into St. John county and along the lower St. John river. While the exact position of the several divisions of the Huronian has not yet been definitely determined, sufficient has been learned to warrant certain changes in the distribution as defined in the published map of the district. Great portions of the Huronian are known to be igneous in character instead of sedimentary as was at one time supposed.

The Pre-Cambrian of Charlotte county has already been referred to in the notes on the Laurentian. In the St. John River areas, as in Kingston peninsula, the rocks are also largely igneous, consisting of felsites, both reddish and grey, which are cut by great masses and dikes of green diabase. On Kennebecasis island, Milkish head, and on Long island, areas of Cambrian slates and crystalline limestones are found, but the relations of these are rather with what was formerly styled the Laurentian than with the Kingston division, and the contacts are more of the nature of intrusives than of overlying sediments. In the ridge north of the Long reach of the St. John river, composed also of felsites, diorites and hornblende schist, these are overlaid by the purple beds of the Etcheminian (Cambrian) and there are pebbles in the lower conglomerates derived from the rocks of this ridge. This is the belt of rocks which extends across into Charlotte county, coming to the coast west of Ragged head on the west side of Lepreau and extending thence nearly to Beaver harbour.

Along the south side of the Long reach, between Elmsdale and Carter point, the shore shows large ledges of diabase and granite rocks, all clearly igneous in character. These in the published map were coloured as Upper Silurian on the supposed evidence of fossils. A careful search during the past year failed to find any organic remains, as the rocks were volcanic. Along the shore occasional patches of altered slates are seen with the felsite, but no traces of Upper Silurian sediments were here seen.

As regards the Coldbrook and Coastal some changes were also noted. Portions of the former were observed to be intrusive in the Etcheminian, and the character of the rocks throughout was igneous. In the Coastal division east of St. John a part of this division which is highly schistose was separated and placed in the Devonian. This included a part between Cape Spencer, east of St. John, and the mouth of the Black river, and on the west it included a considerable area in Pisarinco peninsula between the east shore and Musquash harbour. Farther west it included a belt extending as far as Dipper harbour. In character these rocks resemble Pre-Cambrian schists.

but a re-examination showed them to be highly altered Devonian sediments. On the promontory known as Taylor island the red rocks of the Bloomsbury division are cut by huge masses of green and epidotic diabase, and masses of the red slates are caught in the ingneous rocks. This series of igneous rocks of comparatively recent date extends along the south side of the post road from St. John to Lepreau and was, on the published map, coloured as Pre-Cambrian (Laurentian). Farther east of St. John the Coastal still remains as Pre-Cambrian, in large part underlying the Etcheminian Cambrian, and this belt of rocks extends from the vicinity of Black river to the east end of Caledonia mountain in Albert county. To the north of this certain areas, once coloured as Pre-Cambrian, can now with great propriety be styled intrusive rocks of much later date.

The rocks of the St. John group, or Cambrian series, were, until 1865, as already stated, regarded as an integral part of the Devonian system. The early researches of Messrs. Hartt and Matthew on these rocks have been alluded to in former pages, but of late years their fauna has been particularly studied by the latter gentleman, whose investigations have brought to light many interesting facts relative to the palæontology of the group, the results of which have appeared, from time to time, in several papers contributed to the Royal Society of Canada and elsewhere. The lowest recognized portion of the Cambrian containing fossils consists of purple quartzose sandstones and conglomerates, with shales, the former apparently derived from the underlying groups. These are succeeded by red and greenish-grey argillites, often micaceous, whitish and grey sandstones, with grey and dark grey sandstones and shales, the latter of which are often fossiliferous, and contain a variety of trilobites, such as *Conocephalites, Microdiscus, Agnostus* and *Paradoxides,* all of Primordial type, together with *Lingula, Obolella, Discina* and *Orthis.* They lie in well defined basins upon the Huronian rocks. At least six of these Cambrian belts are known. Among the most important are the areas in the city of St. John and the great development which extends thence northeasterly past the Loch Lomond lakes towards the upper part of the Hammond river. Other areas consist of outlying patches, which have apparently escaped denudation, and which serve to illustrate the great dislocations by which, in many cases, these rocks have been affected. The smaller areas about Kennebecasis bay are overlapped by Upper Devonian sediments.

Though no fossils of value for determination have yet been found in the crystalline limestone and associated slate and quartzite which occur, in the western part of St. John city, and between that place and the Kennebecasis, the marked similarity between the slate and quartzite beds so associated, and those of portions of the Cambrian proper, points strongly to the supposition that these rocks with the limestone bands or lenses, formerly supposed to be a part of the Laurentian series, may properly be placed in the lowest Cambrian system. The fact that these, as well as the Etcheminian division of the Cambrian, are cut by the same series of igneous rocks which were formerly regarded as a part of the Coldbrook Huronian, and have been altered along the contacts, makes the whole question, in the absence of characteristic fossils, difficult to determine definitely.

The Cambro-Silurian system, as at present understood, comprises all the formations between the Potsdam sandstone and the Hudson River or Lorraine shales, both inclusive. In New Brunswick the subdivision into intermediate groups has not yet been attempted the rocks of the series being entirely different in character from those found in Quebec and Ontario. The system comprises certain rocks known, for the most part at least, to underlie the fossiliferous Silurian, and to overlie the Cambrian. The characters of these have already been given.

In their distribution the rocks which were supposed to be of Cambro-Silurian age, in 1878-79, form a belt, principally of metamorphosed sediments, extending from the western boundary of the province diagonally across the county of Charlotte to its northeast corner, flanking on its north side the great granitic area for the greater part of the distance. Thence it extends to the River St. John, in the vicinity of Hampstead, and, reappearing on the eastern bank, continues along the county line of Kings and Queens for a further distance of twenty miles. The northern limit is fixed, for the most part, by the unconformably overlying interior basin of Devonian sediments; but to the west, at the head of Oak bay, and to the east of the granite area in southwestern Queens it is overlapped by strata of Silurian age. Much of the country occupied by these rocks is exceedingly difficult of access, and a more detailed examination has changed somewhat the outlines of the area as defined. Large portions of these rocks have recently been transferred to the Upper Silurian, which is the horizon at which they were placed more than thirty years ago.

Rocks of the Silurian system occur at several places in the southern part of the province. Along the coast of Charlotte they are found sometimes in small lenticular basins, which have been enfolded with areas of other rocks largely along the shores of Passamaquoddy bay; the association being intricate and often obscure, as in the case of the Mascarene series. Certain beds are, however, well defined by the presence of characteristic fossils, which are probably of the horizon of the Niagara formation. The fossiliferous beds are also well seen around the upper part of Oak bay, and from this place they extend in a continuous belt along the south side of the granite area as far east as New river, a distance of thirty miles . In the southeastern part of the province they have not been definitely recognized; but along the St. John river, in the vicinity of the Kings and Queens county line, they form a considerable area, abounding in fossils at many points, and resting unconformably upon the rocks of the Huronian and Cambrian systems.

The Devonian system has a considerable development in the southern portion of the province, and contains many points of interest. It is noted for the abundance of the plant remains which have been obtained largely from one of the lower members, the Dadoxylon sandstone, and from its yielding the earliest remains of insect life yet known, at least in America. The flora, both from the formations in New Brunswick and from Gaspé, were carefully studied by the late Sir William Dawson many years ago, and the results have appeared in a series of papers, ranging in date from 1859 to 1882, which have been readily accepted as standards for the determination of the several divisions.

The rocks of the system have been divided into five groups, viz., Bloomsbury at the base, Dadoxylon, Cordaite shale, Mispeck and Perry. Of these the first is largely made up of igneous rocks which cut across and sometimes occur in large masses, associated with certain beds of reddish conglomerate, sandstone and shale. These sediments pass up into the Dadoxylon sandstone and shale, generally greyish, sometimes abounding in plant remains, the lower beds occasionally changed to a hard quartzite. Many of the plant remains are in a fine state of preservation, including in the shale beds several kinds of ferns, with insect wings and remains of crustaceans.

The Cordaite division consists of greenish-grey and purple-tinted shale and sandstone, in certain portions of which remains of Cordaites are abundant and well preserved, whence the name of the division. These rocks pass up without apparent break into the Mispeck division which contains numerous beds of conglomerate and is often purple tinted. Above all are the Perry conglomerate and snadstone series, generally reddish-brown in the lower portion, but gradually passing up into greyish beds of grit, shale and sandstone, with occasionally conglomerates which appear to constitute the upper part of the Devonian series. In these upper grey beds plant remains are often abundant, certain forms being similar to those found in the Gaspé series.

In certain places the Devonian rocks are much altered, passing into schists of Pre-Cambrian aspect, and occasionally they are cut by masses of diabase, with sometimes a great development of quartz in the form of veins and large masses; so that in this system we have in the vicinity of St. John, on the east side of Courtney bay, a regular sequence of the different formations from the Bloomsbury division at the base to the upper or Perry group. The flora from this upper division closely resembles that from what is known as the Horton series as seen on the Avon river in Nova Scotia. In that portion between the red conglomerates and the upper grey shales is situated the series of bituminous shales, that in Albert county hold the peculiar mineral called 'Albertite' and known usually by the name 'Albert shale,' and which form a well-defined area extending from near the village of Hampton on the west into Westmorland county near Dorchester and Memramcook on the east.

Along the coast of the Bay of Fundy east of St. John the areas of the Devonian are somewhat limited, the principal being that already referred to east of the harbour at Courtney bay. Here the rocks occupy a true basin and extend from Little river on the north to Cape Spencer on the south. They are here in the form of a double syncline which extends inland for about eight miles. Farther east the upper or Perry division extends along the coast as far as the village of St. Martin, the rocks in places being much broken up and sometimes altered. Still farther east they again appear on the coast of Albert county and can be followed from Cape Wolf to Shepody mountain, both the Perry conglomerate and the upper grey plant-bearing shales and sandstone being well exposed, especially in that part between Cape Enrage and New Horton where the strata are highly tilted, sometimes reaching the vertical.

Inland the Perry formation occupies the shores of Kennebecasis bay and several islands there, and then continues eastward along the valley of the Kennebecasis river as far as Sussex, where it becomes covered in part by the unconformably overlying beds of conglomerate, limestone and gypsum of the Lower Carboniferous formation. The Perry beds again appear and have a considerable extent in eastern Kings and Albert counties where the Albert shale portion is well developed.

West of St. John the several divisions are also well exposed. The Bloomsbury red beds with the igneous epidotic masses show in the Carleton portion of the city, whence they continue at intervals to the village of Musquash, followed in ascending order by the other divisions into the Perry, which is well seen at Point Lepreau resting here upon the Dadoxylon sandstone. The intermediate divisions are highly altered about Piscarinco and in the portion west of Musquash harbour, becoming crystalline schists with masses of igneous rocks, often felsites or rhyolites.

The Perry rocks west of Lepreau show at a number of points on the coast of Charlotte county, but are especially developed about the town of St. Andrews when they cross the St. Croix and pass into the State of Maine, where they have been recently studied, as regards their flora, by Mr. David White, of Washington, by whom their Devonian age has been declared.

The largest area in the southern half of the province is found underlying the central Carboniferous basin. This, beginning at the boundary of Maine, extends to the St. John river, and has in Charlotte county a breadth of about twelve miles, bounded on either side by rocks of Silurian age. That it underlies a very considerable portion of the Carboniferous central basin is seen from the occurrence at intervals, as about the head of the Grand lake and on Canaan river, of outcrops of Devonian slates, sometimes in the beds of the streams where they are unconformably capped by the Millstone-grit division. These Devonian strata have apparently participated in the series of disturbances which affected all the formations in the southern part of the province older than the Carboniferous.

In the western portion of the province outcrops of the conglomerates of Perry age are seen in Carleton county a short distance above Woodstock, whence they pass northeast and cross the St. John river two miles south of the village of Hartland. Here they spread out and form an area of considerable extent to the eastward, resting upon Upper Silurian rocks. These grey beds associated with these red conglomerates also contain plant remains similar to those which occur with the upper grey beds of the Perry in St. John county. It is also probable that a portion of the area along the Tobique river in the vicinity of Plaster Rock, and on several streams to the south, should be assigned to the horizon of the Perry division, but the details of this area have not yet been worked out.

The Carboniferous system is divided into three parts, viz., the Lower, the Middle and Upper. The Middle division in Nova Scotia is subdivided into two portions, the Millstone-grit and the Productive coal measures. Of these in New Brunswick, apparently only the first is represented, the coal seams known in the province belonging to this division and the true coal measures being absent.

To the Lower Carboniferous division belong the marine limestones and the gypsum deposits. These are usually regarded as constituting the base of the entire system; but with them are associated certain conglomerates, sometimes greenish and sometimes reddish, which rest upon the upper part of the Devonian. Above the gypsiferous measures other conglomerates with marly reddish shales occur, which directly underlie the grey Millstone grit conglomerate. As a rule the Lower Carboniferous beds are but little disturbed, their inclinations being at low angles, though thrown into undulations. In places near the base, intrusive masses of diabase and rhyolite, sometimes porphyritic, occur, and some of the largest deposits of manganese in the province are found near the bottom of the series at the contact of the limestone with the old rocks, as at Markhamville and at Jordan mountain.

The general characters of the Carboniferous formations, as given from the time of Dr. Gesner, down to the publication of the general map in 1878-79, have been described in considerable detail in the preceding pages.

The total area of Middle Carboniferous rocks is about 12,000 square miles, throughout which great uniformity of character is apparent. Over the greater portion extends a thin seam of coal which crops out on Grand lake and on the Richibucto river, where it has been worked for many years, and at various other points along its entire border. This seam, while varying slightly in thickness, in no place, however, amounting to more than twenty or twenty-three inches, is very uniform in general character; and it is probable that all the outcrops noted pertain to the same seam, brought to the surface at intervals by a series of low anticlines which affect the measures throughout their entire extent, following generally a course parallel to the Pre-Cambrian ridges which surround the basin on the south and northwest. Throughout the counties of Kent, Northumberland and Gloucester, which comprise the area bordering on the Gulf of St. Lawrence, the character of the sediments is similar to that of the recognized Millstone-grit areas of the Bay of Fundy coast, though the horizontality of the beds is such that but little information can be obtained from surface examination as to the entire thickness of the formation. In eastern Westmorland the investigations of 1884 resulted in the discovery of many interesting facts in regard to the structure and thickness of the several formations comprised in this system.

The thickness of the Middle Carboniferous in the central basin, as given in the report for 1872-73, has also been considerably changed by the study of the rocks farther east. Thus the three divisions above the Lower Carboniferous were at that time regarded as follows :

Barren measures probably Millstone-grit. . . .	200 feet.
Productive.	200 "
Upper Carboniferous.	200 "

This view was modified in 1878, and the whole interior area was referred to the horizon of the Millstone-grit. The sections of this formation in the vicinity of Dorchester have shown that it has a thickness of at least 1,000 feet, and that it is directly overlapped by the Upper Carboniferous formation which extends thence over a considerable part of eastern Westmorland county, occasionally broken by the presence of ridges of Millstone-grit rocks. Where the contact is not with the Millstone-grit the Upper formation rests directly on the Lower Carboniferous, which arrangement is also seen in the adjoining province, in the area lying south of Northumberland strait.

The westward extension of the magnificent Joggins section touches the coast of New Brunswick only in its lower part ; the Productive measures, in which the Joggins coal seams are found, trending out into the bay, and being exposed on no part of the shore of the province. The general horizontality of the measures shows that the disturbances, which so profoundly affected the coal-fields of Spring Hill and Pictou, did not extend in this direction, while the apparent absence of the coal measures over any portion of New Brunswick, in so far at least as can be at present determined, leads to the assumption that this area was for a considerable period already permanently raised above the sea.

Several outlying patches of the Middle Carboniferous are seen at points outside the central area. In character of sediments they do not differ from those already described, and contain also a thin seam of coal. Among these may be mentioned that of Prince William, about twenty miles west of Fredericton, and at Dunsinane on the railway between Sussex and Petitcodiac.

Extensive traces of volcanic activity are manifest at many points, especially in the Lower Carboniferous formation. Thick beds of ash rocks, conglomerates and breccias, together with various traps, are found, not only around its border, but in isolated hills which, by the agency of denudation, now appear prominently from beneath the grey sandstones of the Millstone-grit in the very centre of the coal district. In places, these trappean masses are apparently overflows from dikes which have cut the lower beds of the Lower Carboniferous, and have altered these along the contact in the same manner as the sandstones of the Bay of Fundy have been affected by the trap outflows of the Triassic time.

The Triassic formation is well seen about the village of St. Martin on the north shore of the Bay of Fundy, about thirty miles east of the city of St. John. As exposed on the shore it consists of bright red, rather soft sandstone, which rests in part upon the Perry conglomerate and sandstone and in part on igneous rocks of St. Martin head. Inland, the sandstone becomes associated with pebbly conglomerates and with interstratified sandstone and shale. Traces of plant stems have been observed in these beds, but have not yet been definitely determined. The formation extends east from the village as far as Melvin beach, a distance of seven miles, and has a breadth inland to the foot of the mountain range of about two miles, occupying a basin-shaped area, the northerly dips seen along the shore changing to the south near the contact with the underlying rocks inland.

Other small areas are seen in Albert county on the shores of Salisbury bay to the east, and to the west between Red head and Gardner creek where they also rest upon the Upper Devonian formation.

On the island of Grand Manan the Trias is represented principally by a large mass of trap or diabase, often columnar, sometimes ashy and amygdaloidal, resembling that of the North Mountain range in Nova Scotia. On the west shore of the island at low water small exposures of red Triassic sandstone are reported, similar to those just described.

Leaving for the present the consideration of the igneous rocks, which constitute an important element in the geology of this part of the province, we will now examine the structure of its northern and western portions.

The earlier investigations of Dr. Gesner and others have already been reviewed down to the year 1874. Upon the completion of the map of southern New Brunswick the examination of these sections was at once commenced, the northern part by the author of this paper; the western by Professor Bailey and Mr. W. Broad; while the superficial geology of the district was entrusted to Dr. R. Chalmers. Reports on the former area appeared in 1879-80, 1880-81, by the writer, and on the latter by Professor Bailey, 1882-83-84, and 1885. Investigations were also carried on for a short time in 1879, by Dr. G. F. Matthew, in Carleton county, the results of which were not published separately, but were subsequently embodied in the report by Professor Bailey on the area in question.

The difficulties encountered in tracing out the various formations were far greater in this section than in that already described, owing to the fact that, with the exception of narrow belts of settled lands in the vicinity of the St. John river on the west, and along the shores of Chaleur bay on the east, and for a short distance inland along the course of the principal streams, the country is an entire wilderness; the only means of access to its interior is by canoes along the various rivers which rise in close proximity to each other in the series of mountains constituting the watershed. Of these streams the principal flowing to the east are the Restigouche, Nipisiguit and the branches of the Miramichi; to the west the Tobique, and several other large branches of the St. John. From the explorations that have been thus carried on the following systems have been clearly recognized:—

Pre-Cambrian......Comprising gneisses, syenites, schists of various kinds and felsites.

Cambro-Silurian	Which, as in southern New Brunswick, may also comprise limited areas of Pre-Cambrian, and even Cambrian rocks, at present not separable.
Silurian	Limestones, slates and sandstones, often highly fossiliferous.
Devonian	Principally developed about Chaleur bay, and in Gaspé peninsula, but also as patches overlying the Silurian rocks inland.
Carboniferous	Lower or Bonaventure formation. Middle or Millstone-grit. Upper, along the shore of the Gulf of St Lawrence and Northumberland straits.
Volcanic or Igneous rocks.	

In the study of the Pre-Cambrian areas of northern New Brunswick no attempt has yet been made to separate the divisions of the Pre-Cambrian; since, in the present largely inaccessible condition of the country, such separation must of necessity be very imperfect. Various rocks occur which approach very closely in character to the oldest rocks of St. John county, and which, apparently, form the lowest members of the Pre-Cambrian series, being clearly distinguished from the upper or schistose portion. Of the former are the gneisses and syenites, with certain felsites, which are extensively developed about the headwaters of the Nipisiguit river, whence they extend southwesterly, crossing the upper part of the south branches of the Tobique; but it is worthy of remark that in all the areas of these rocks yet examined in this portion of the province, no traces of the crystalline limestones which are so conspicuous in the older rocks of southern New Brunswick have yet been found. On the Tetagouche river beds of graphitic, and to some extent crystalline limestone, occur, which resemble somewhat those of St. John, but their intimate association with blackish slates that belong to the Cambro-Silurian graptolitic series near the mouth of that stream renders it probable that these may belong to that horizon, and that their alteration is due largely to local intrusions of dioritic masses, in the same way as is seen in the alteration of the fossiliferous Silurian limestones into marble near Chaleur bay.

In general, the Pre-Cambrian rocks of this section greatly resemble those of the recognized divisions already described. There is probably, however, a greater preponderance of true felsites, and a smaller development of the ashy or volcanic portions of the Coldbrook and Coastal groups, but felsitic, chloritic and talcose schists, epidotic rocks, gneises, etc., are common at many places throughout the area in question. They occupy an extensive tract of country extending diagonally across the northern portion of the province, from a short distance above the Forks of the Main Southwest Miramichi, on the west, nearly to the mouth of the Jacquet river, on Chaleur bay. The greatest breadth of this area, on a line drawn across to the head of the Tobique river, is about forty-five miles, in which is included a breadth of twelve miles of intrusive granites. The principal area regarded as Pre-Cambrian is overlapped by the Silurian on the east, a short distance after crossing the Tetagouche river, on which stream its southern boundary is seen about sixteen miles from its mouth. The Silurian rocks here occupy an elongated basin, extending inland for some distance beyond the upper waters of the Upsalquitch river, bounded on the north by the prolongation of the felsite area, which can be traced continuously from the Tobique lake across the latter stream, and along the north side of the Jacquet river nearly to its mouth. On the upper part of the Upsalquitch, gabbros are associated with the gneisses that constitute the high hills in this vicinty; but along the watershed which divides the streams flowing into the Gulf of St. Lawrence, viz., the various branches of the Miramichi, and those into the Tobique, the Pre-Cambrian rocks have been broken through by a great mass of granitic and syenitic rocks, precisely similar in character to those of Charlotte county. The southern margin is also for some distance bounded by similar granites, which are extensively exposed on the upper part of the Main Southwest Miramichi and its tributaries.

On all the streams which flow east between the Nipisiguit and the Main Southwest Miramichi the rocks called Pre-Cambrian are easily recognized. Their intense degree of metamorphism, regional rather than local, distinguishes them from those of the overlying formations, while in many places there is a marked unconformity between them. The western boundary of the series is seen on Nictor lake, which is at the head of the Tobique river, in several islands and in the great peak known as the Bald mountain, whence a high chain of hills extends to the right hand branch of the Tobique, crossing it a short distance below the forks of the Campbell and Serpentine rivers, and continuing with a more southwesterly trend to the forks of the Miramichi. On the Nipisiguit its eastern boundary is seen a short distance below Indian falls, not far from the 47 mile post on this stream. The northeastern area is divided into three parts by basin-like overlaps of Cambro-Silurian and Silurian strata, presently to be described.

To the south, the Pre-Cambrian is overlaid principally by rocks of the Cambro-Silurian and Cambrian systems, and on the west by sediments of various ages, up to the Lower Carboniferous.

The Cambro-Silurian and Cambrian rocks resemble those of the areas already described under this head in previous pages. They consist of slates, grey, red, and black, with quartzose sandstones, sometimes schistose, and when in contact with the granites contain abundance of crystals of staurolite, mica, etc. Certain bands of the red and green slates are persistent for long distances, and can readily be traced from their northerly terminus on Chaleur bay southwesterly into the county of York. In character these slates of various colours, with their associated sandstones, resemble very closely certain beds of the Lévis and Sillery divisions of the Quebec group, and this resemblance is strengthened by the occurrence of graptolites, in some of the graphitic layers, similar to those found in that group. As in the southern portion of the province, certain areas of highly metamorphic rocks also occur, which lithologically closely resemble Pre-Cambrian; but as in the case of the more southern area, these are so intimately associated with other sediments as to render their separation impossible for the present. The alteration of many of these sediments is probably in part due to local intrusion of igneous rocks, and in part to the folding to which they have been subjected.

The rocks now considered of Cambro-Silurian, and in part of Cambrian-age, are in great part those described by Drs. Gesner and Robb as Cambrian, while in the map accompanying *Acadian Geology* they were comprised under the term Lower Silurian. To the southwest they occupy a large portion of the county of York, whence they extend into the adjoining state of Maine. In this direction they are directly overlaid by Carboniferous sediments of the central basin, the Devonian and Silurian being largely concealed, or, at best, represented only by detached outliers of very limited extent. Their northwest outline crosses the International Boundary into Maine, about two miles south of what is known as the Monument, at the source of the St. Croix river, whence, trending northeasterly, it crosses the St. John river a little to the north of Woodstock, and extends nearly to the headwaters of the Tobique. Recent investigation has shown that in this belt are included areas of fossiliferous Upper Silurian, more especially in that part between Canterbury and Benton on the line of the Canadian Pacific railway.

Areas of limestone which are sometimes crystalline and micaceous are found as an integral portion of the system in the western area near Canterbury. These resemble in some respects the crystalline limestones of St. John, and are associated with quartzites and schistose rocks. The occurrence also of somewhat similar limestones in the eastern area as a part of the same formation has already been referred to.

While then, the Cambro-Silurian and Cambrian rocks have a somewhat extensive development in this section of the province, their bulk is much reduced by the presence of large masses of syenite and granite of undoubtedly much later date. These have penetrated the surrounding beds, into which large dikes and veins are intruded in all directions, while huge pieces often have the appearance of having torn from their original position, and of being now held in the igneous mass. Their action on the slates and sandstones is marked, not only by the generation of crystals of various kinds, but by a general alteration of the contiguous beds into schists and gneisses containing mica.

Two principal areas of these rocks are seen, the more southern flanking the south side of the Pre-Cambrian axis of the interior, and continuing to the shore of Chaleur bay, north of Bathurst, the other on the northwest side of the axis, terminating, as described, near the headwaters of the Tobique. These areas are distinctly unconformable to the underlying series. They are not, as a rule, rich in fossils, but at several points in the southern belt, notably on the Tetagouche and Miramichi rivers, different forms are found, including brachiopods, as well as graptolites. These, while in many cases too indistinct for perfect determination, present features more nearly allied to Cambro-Silurian forms than to those of any other horizon; but in the western belt, more especially on the North branch of the Becaguimec river, in Carleton, a wonderfully mixed fauna is found in a somewhat limited space. At one point on this stream, near Shaw's mill, strata, holding fossils which appear to belong to this system, are apparently interstratified with others containing Silurian forms, while in close proximity are beds filled with remains of *Psilophyton*. There would, therefore, in this locality, appear to be three systems represented, of which the Silurian forms seem to be near the base or junction with the Cambro-Silurian. This peculiar admixture of so many different horizons can probably best be explained on the hypothesis of intimate enfolding and subsequent denudation, by which narrow crests of older ridges are exposed. In addition to the fossils recently found at this place, several small outlying patches were noted, and first referred to, by Mr. C. Robb (Rep. Geol. Sur., 1869). and others were subsequently discovered by Mr. McInnes, in northern York; but these appear to be more closely allied to Lower Helderberg forms, and consequently quite distinct from the rocks of the principal Cambro-Silurian area upon which they rest at limited outlying patches.

The view taken by Professor Hind of this portion of the rocks in northern New Brunswick, as representing the Quebec group of Canada (see his Rep. 1865), has thus been fairly sustained by later investigation, both on grounds of lithology and palæontology. The similarity also of the fossils of the Becaguimec area to those of the Lower Trenton group, to which horizon, a portion, at least, of the fossiliferous Quebec group belongs, is also evident, and leads to the conclusion that a repetition of these rocks, both in their fossiliferous and metamorphic stages, is found in this section of the province.

But by far the most extensive of the older geological systems in this area is the Upper Silurian. This occupies the entire country along the St. John river above Woodstock, extending across the Restigouche river into the adjoining province of Quebec, together with the greater part of the valley of the Tobique, where it is, however, to some extent overlapped by Lower Carboniferous sediments. Thence it extends to Chaleur bay; occupying, with the exception of the supposed Pre-Cambrian belt of Jacquet river, and sundry areas of diorite and trappean rocks, the remaining portion of the province to the north, and including the valley of the Restigouche and its tributaries, as well as a large portion of the Gaspé peninsula, where it rests upon the southern flank of the Quebec group.

The strata of this system are thrown into a series of anticlines, gouche river into the adjoining province of Quebec, together with the axes of which are well exposed on the various streams, and the beds are in places highly fossiliferous, the different formations from the Niagara to the Lower Helderberg, both inclusive, being already recognized. They are frequently penetrated by dikes and masses of trap, often of large extent, some of which, as at Dalhousie, are intercalated sheets between the fossiliferous limestone and shales, which have been altered along the contact. The Silurian here contains traces of plant stems, which are probably the oldest found in the province, and are associated with distinctly Silurian forms. The same association of plants in Silurian strata is found in the Gaspé limestone series near Gaspé basin, and was referred to by Sir Wm. Dawson in 'The Fossil Plants of the Silurian and Devonian, 1871.' It is also possible that the plant stems noted on the Becaguimec may be in the upper beds of the Silurian, though their aspect at this place is more markedly Devonian.

The rocks of the Devonian system occupy but limited areas in this section, and are, for the most part, confined to the vicinity of the upper portion of Chaleur bay. Several small outliers, have, however, been recognized in Carleton and Victoria counties, the fossils of which would place them near the base of the series. Of these, the former is found near the junction of the Becaguimec with the St. John, where certain black shales are exposed in a narrow band containing abundant remains of *Psilophyton princeps*, a characteristic

Devonian form (see Rep. Geol. Sur., C. Robb, 1870-71). This area is largely concealed by Upper Devonian conglomerate, and sandstone, which occupy a basin formed by the branches of the first-named stream.

In the section along the Upsalquitch river, a branch of the Restigouche from the south, a basin of Devonian sandstone and shale, with characteristic plants, was observed to rest unconformably upon Silurian rocks. Its extent inland could not be traced, as the surrounding country is densely wooded. As at other points, the sediments were intersected by trappean masses, the metamorphic action of which was quite evident and proved their more recent age.

On the Lower Restigouche, areas of Devonian rocks are found on both sides of the stream which forms the dividing line between the provinces of New Brunswick and Quebec. These, on the south side, extend at intervals from a point three miles above Campbellton, to within a couple of miles of Dalhousie. The shales and sandstones contain plant stems, descriptions of which are given in the report of 1879. In the vicinity of Campbellton, also, beds of brecciated limestone or calcareous breccia have yielded a comparatively rich fauna of Devonian fishes such as *Cephalaspis, Coccosteus*, etc., representing the lower part of the system, while on the side of the river opposite Dalhousie, other beds contain an abundance of fossil fishes, which have been described by Dr. Whiteaves, and appear to indicate its middle or upper portion. It is of interest to note that as early as 1842 these remains were recognized by Dr. Gesner, who, however, regarded them as reptilian in their character. He supposed the containing beds, from their lithological aspect, were portions of the New Red Sandstone or Carboniferous formations, and it was not until 1879 that these interesting fossils were rediscovered by the writer and the true position of the beds established. The Devonian of this locality occupies a shallow syncline. The strata are penetrated by trap dikes, two periods of eruption being evident from the fact that the lower beds at Campbellton, in which the fishes were found, are composed largely of trappean débris, as also from the presence of pebbles of trap in the conglomerates elsewhere, and from the occurrence of fossiliferous strata overlying trappean ridges. Later intrusions of volcanic matter through the newer members of the system, both here and at various points in the Gaspé peninsula, are also common.

The Carboniferous system is represented in northern and eastern New Brunswick, principally by the upper portion of the Lower formation, styled the Bonaventure, and the lower or Millstone-grit portions of the middle division. The development of the latter over the great inland basin has already been referred to, and but little more need be said concerning it. Along the south side of Chaleur bay a thin seam of coal occurs at several points, which has the same general character as in the interior. On the island of Shippigan, and on the mainland north of Tracadie, soft, red micaceous sandstone is seen, which probably represents a part of the Upper Carboniferous, but these areas are confined to a narrow fringe along the shore. A similar thin seam of coal is found on several of the branches of the Miramichi, and gives strong evidence that the formation has no great thickness at any point. The area is traversed by several low anticlines, of which four principal ones are recognized and described in Rep. Geol. Sur., 1882-83.

The more northerly of these extends between Bathurst and the Miramichi river, where it forms a ridge running northeasterly, with an elevation of between 500 and 600 feet. The second extends from the head of Grand lake to the vicinity of Richibucto head on Northumberland strait. This brings up the Devonian rocks of Coal creek.

The third passes to the north of Moncton, indicated by the ridges of Indian mountain, and reaches the shore a few miles north of Shediac; while the fourth, which affects the southeastern area only, is well seen in the Aulac ridge which extends to Bay Verte, and thence in a low rise runs through the Tormentine peninsula to its extremity.

The basin of Middle Carboniferous rocks is underlaid along nearly its entire boundary on the north, west, and south by the Lower Carboniferous. At one or two points, however, notably on the Dungarvon and Renous rivers and on either side of the St. John river, west of Fredericton, the lower members are concealed by the overlap of the Millstone-grit, directly upon the Silurian. The volcanic portion of the Lower Carboniferous, though considerably developed in the counties of York and Victoria, is apparently absent from the northern area where the rocks are sandstones and shales with conglomerates, which in the southern part of the province constitute the upper members of the gypsiferous division. They are well displayed along the south coast of Gaspé at intervals to the extremity of that peninsula, (where they received the name of the Bonaventure formation) as well as at several points on the shore north of Bathurst.

On Heron island, which is in Chaleur bay, about nine miles southeast of Dalhousie, the rocks of the Bonaventure formation are well developed. The shales here contain remains of plants which have never yet been described, while the sandstones show impressions of reptilian footmarks, which are the only ones of this age yet found in New Brunswick, though somewhat similar tracks have been recognized at several points in Nova Scotia in strata of not much higher horizon.

IGNEOUS ROCKS.

The principal igneous rocks which have not already been sufficiently described in connexion with the various formations are the intrusive granites and syenites and those of the newer trappean areas.

Of these, the former are much the more important, not only from their very considerable extent but from their economic value. They have been roughly outlined from the time of the earliest report on the geology of the province, but it is only within the last few years that the details, more especially of the northern area which is much the larger, have been studied.

Generally speaking, these two great areas enter the province near its southwest corner from the adjoining state of Maine. Along the border in Charlotte and York counties they are separated by a considerable extent of slates already described. The southern belt extends entirely across the former county, and occupies a large part of western Kings and Queens, reaching, with some interruptions, to the St. John river. Farther east, in the latter county and in Westmorland, isolated outcrops protrude through Carboniferous sediments revealed by the denudation of the latter. That these are of earlier age than the overlying beds is proved by the débris of the granites being found in the lowest member of the Lower Carboniferous and Upper Devonian formations. Similar areas of granite are also associated with the Pre-Cambrian of the southern part of the province, but these are comparatively limited in extent as compared with the principal granitic mass. In character these rocks are very similar, being generally reddish and moderately coarse grained, often with large crystals of feldspar. In places, however, the texture is fine and the colour grey.

The northern area, while of greater extent, presents a similar aspect. Crossing from Maine through the chain of the St. Croix lakes, which form the boundary for some distance, it enters the province in a belt more than twenty miles in width, and extending northeasterly, crosses the St. John river midway between Fredericton and Woodstock. Fine sections are afforded by the river, which cuts directly through the belt, showing well the intrusive character of the rock by the number and nature of the dikes, which are sent off in all directions into the adjoining slates, as well as by the distinct local metamorphism, due directly to the presence of the granitic mass. Crossing the River St. John, the granite subdivides into two portions, the more southerly of which terminates near the New Brunswick railway, while the northern band crosses that line and continues to a total distance of thirty miles from the river. North of this, to Chaleur bay, the granites occur in three distinct areas, of which the two central are of large extent, and are, for the most part, associated with Pre-Cambrian rocks, though also penetrating strata of Cambro-Silurian age, on the Miramichi river. On this stream the alteration along the contact, both of the slates and granite, is well seen, the latter, for several feet, becoming fine-grained and whitish in colour, while the former are in places shattered and contain crystals of various kinds. The second area occupies a great breadth of country about the headwaters of the South branch of the Nipisiguit, and on the Northwest Miramichi, forming an exceedingly hilly and broken surface, containing some of the highest peaks of the province. The third area occurs on the lower part of the Nipisiguit near Bathurst, and extends for some twelve miles up from its mouth, but is concealed on the lower portion for three miles by Lower Carboniferous beds, the base of which is made up of granitic débris.

From a consideration of the various points of contact the intrusive character of these granites is very clearly established; since, in no other way, can the peculiar phenomena seen be accounted for. There is, however, a marked difference in the character of the metamorphism resulting from the granite, as compared with that produced by the intrusion of the dioritic or trappean masses. In the former the alteration is more gradual, and extends over a much wider area as though continued for a considerable period, and probably under great pressure. In the latter case the rocks in contact have frequently a baked or porcelainized aspect, as though exposed to a quicker but not so prolonged a heat. This may perhaps be more clearly expressed by regarding the granites as *intrusive* rocks proper, which have not reached the surface at the time of their intrusion, but cooled beneath the surface and were subsequently exposed by denudation, while the latter may be held as rather *extrusive,* coming to the surface along direct fractures or lines of bedding ,and cooling rapidly.

Of the other kinds of intrusive rocks some of the diorites and felsites doubtless are, as heretofore described, integral parts of the older formations. The metamorphosing action of the granite and diorite is seen in beds of Silurian age, so that it is evident its intrusion must have been subsequent to that period; while, as no pebbles or débris are found in any formation older than the Devonian, the age of these great masses cannot be far from the beginning of that era. Many of the older volcanic rocks of the Pre-Cambrian areas have an earlier date than the overlying Cambrian strata, since their débris enters largely into the composition of the basal beds of that system.

The areas of serpentine in the province are too limited to form any particularly distinctive feature. Sufficient evidence, however, exists to indicate its connexion with the igneous rocks, probably as a product of alteration, as seen in the serpentinous diorites of western Charlotte county and elsewhere.

The trappean rocks, which are largely developed along the lower Restigouche, and along the upper part of Chaleur bay, are, like the granites, for the most part of Devonian age. In places, dikes of considerable size cut directly through sandstones and shales of this age, or throw them upwards into low anticlines, in the same way as the traps of the Bay of Fundy have affected the Triassic sandstone of that locality. In places, also, the conglomerates of the period are largely made up of trappean dêbris. It would thus appear that at least two periods of volcanic eruption occurred in this region, of which the earlier was probably the more extensive; since by it the huge mountains of Dalhousie, Campbellton, and the range along the north shore of the Restigouche to Tracadie Gash mountain, were brought into their present position, upon the flanks of which nearly horizontal beds of Devonian age have been deposited at various points.

There yet remain to be considered the great masses of felsitic rock of various ages, both of the southern portion of the province and of the great areas of the northern division. That the great bulk of these are true volcanic products is evident from their nature. Their character as amygdaloids, agglomerates and ashbeds, together with the existence of highly crystalline feldspar porphyries, trachytes, rhyolites and similar rocks, clearly establishes their eruptive origin. That they are, however, of different ages, is plain, since while some of these are undoubtedly of Pre-Cambrian age, and form what is known as the volcanic portion of the Huronian system, others are intimately associated with Silurian, Devonian, and Lower Carboniferous strata, either as great masses or as interbedded sheets. These latter are, however, as a rule more earthy than the older series, and their mode of occurrence clearly indicates their later age.

A large area of felsitic and other igneous rocks occurs on the Tobique river, the age of which is somewhat doubtful, and much of it is highly crystalline and porphyritic, and resembles the old Pre-Cambrian felsite of the interior; other portions are ashy. It is separated from the main area by a band of Cambro-Silurian slates, which may only occupy a basin-shaped valley in the older rocks, but the impenetrable character of much of the country renders it at present almost impracticable to determine its true horizon, and it is possible that it may in part pertain to the Lower Carboniferous outlier of this locality, with the rocks of which it appears to be intimately connected. Other areas of epidotic and dioritic rocks of uncertain position occur in the vicinity of the St. John river, near Woodstock; they are associated with Cambro-Silurian and Upper Silurian strata.

SUPERFICIAL GEOLOGY.

The superficial geology of the province has, since the report of Professor Hind (1865), been more particularly studied by Messrs. Matthew and Chalmers, whose reports embody not only their own observations on the subject, but many of the notes collected by the other explorers in this field.

That by Professor Hind furnishes much valuable information concerning the origin of terraces, raised beaches, and lake basins, it also gives a list of glacial striae and ice grooves, from the particulars of which he infers that the ice might have had a thickness of 2,000 feet, as indicated by the markings found on the tops of some of the mountains. The varying courses of the striae are accounted for on the grounds that the direction of the ice sheet was influenced, to some extent, by the direction of the valleys and other leading topographical features. This peculiarity of local glaciers has been discussed at greater length in recent reports by Dr. Chalmers. The various lake basins were held to be due to the ploughing out of the softer portions of the underlying rocks through the agency of these glaciers.

The reports of Dr. Matthew go much more extensively into detail. In these the superficial deposits are arranged under three heads, viz.:

(1) Boulder clay or till, unmodified glacial drift, constituting the lowest member.

(2) Stratified sand and gravel, Syrtensian deposits, formed by marine action, and representing the remains of old shoals and banks.
Leda clay, estuarine deposits.
Saxicava sand and raised beaches, littoral deposits.

(3) Modern alluvium, shell marls, peat, etc.

The peculiarity of the boulder clay is its unstratified arrangement and its intermingling of sand, clay, and stones, which are often striated. As a general rule it was observed that the boulders were for the most part local, and only at rare intervals were stones found that had come from any considerable distance. Where observed in the southern part of the province, their course was generally from north to south or southeast, more especially in the southwestern and central portions, and good instances of upward transport were seen by their presence on the sides or tops of mountains, 500 feet or more above their starting point.

The colour of the boulder clay was found, as might naturally be supposed, to be affected in great measure by the colour of the rocks from which it was derived, more especially where these rocks were soft sandstones or calcareous shales, since the hard rocks resisted more effectually the degrading effects of the ice sheet. Wherever this clay is removed the strata beneath are, as a rule, found to be rounded and scored, showing that the deposit of the clay was subsequent to the smoothing of the rock. Two principal directions are visible in the striae; to the west of St. John the prevailing course is to the south of east, while to the east of that city it is southwesterly, following to a great extent the principal hill features.

The beds of the second or Syrtensian group differ from the preceding in their stratified character, though there are, at certain points on the coast, indications of a gradual passage from the upper members of the boulder formation into the lower part of the stratified group. The various beds of the latter are arranged by Dr. Matthew under four principal heads, viz.:

The weather shoal, forming under the north side of the hill, or at the entrance to a valley.

The lee shoal, forming behind a hill, or at the outlet of a valley.

Centre shoals, formed in open spaces or enlargements of valleys, or on the higher lands.

Horsebacks, and eskers, formed of gravel and sand along valleys or ridges as connecting neighbouring hills, or opposing slopes of valleys.

The Leda clay may be regarded as an upper portion of the preceding group, since, in the southern part of the province, the beds of the former graduate upward into the latter. It may, however, be properly restricted to deposits of clay, which often rest upon the gravels of the Syrtensian group, and are generally distinguished by the presence of organic remains, in which, in addition to shells of various kinds, the remains of a *Phoca* and a *Beluga* have been found near the coast of the Bay of Fundy. This deposit is well recognized, not only in the southern part of the province, but in the Chaleur Bay area, both in New Brunswick and along the Gaspé shore, from which a large collection of fossil remains has been obtained. The deposit, however, changes its character in different places, from the admixture of sandy beds, and at times it is very difficult to distinguish between the Syrtensian, the Leda, and the Saxicava, owing to their occasional similarity.

To the Saxicava sand are attributed the upper members of the modified drift only. It is generally devoid of organic remains, having in southern New Brunswick produced only two species, a *Mya* and a *Macoma*. It was deposited in gradually shoaling water as the land slowly rose from the sea, and, in this way, terraces of different heights were formed along the coast and river valleys. These terraces, more especially as seen along the St. John and other rivers in northern New Brunswick, have been recently described in detail by Dr. Chalmers, whose papers on the surface geology of these portions of the province are among the most important published on the subject. In many of these terraces the three subdivisions of the modified drift are seen, viz., the Sytensian gravel and sand at the bottom, the Leda clay in the central part, and the Saxicava sand at the top.

On the St. John river a number of sections were made, particularly of the part between Woodstock, and the St. Francis river, as well as along its tributaries, in some of which no less than seven distinct terraces were observed, with a total elevation for the uppermost of not far from 200 feet above the present level of the stream. The highest terraces are composed of stratified gravel and sand with water-worn pebbles; the lower contain the same materials as the upper, but are generally more water-worn, and have local beds of clay and slit. The materials of the kames, or eskers, and terraces are the same and are undoubtedly derived from the same source. Since it has been conclusively established that the valley of the St. John river is of pre-glacial age the mode of occurrence of these deposits is an exceedingly interesting question, and as Dr. Chalmers has evidently given the subject much study, and his views seem to satisfy most of the requirements of the case more fully than any previously advanced—with the proviso that they apply equally well to other river valleys—they are here presented.

'The river valleys, at the close of the glacial period, became very generally choked with drift, which, forming dams, would hold back the water, and constitute a series of lake basins along the river course. These dams, in some places, were from 150 to 200 feet above the present level, hence, the rivers would begin to flow at that height above their present beds. The gradual re-excavation of the drift would, therefore, as it went on, by the transportation to lower levels, result in the formation of the terraces, which would thus mark different levels of the river by the deposition of the materials from higher levels along the border of the lake-like expansions, and along the sides and bottoms of the current, which flowed in and through them; thus, by successive accumulation, forcing the channel from side to side as erosion and deposition went on.

'The kames are composed of similar sand and gravel as the terraces, and may be the remains of these left by denudation of beds once surounding them, and of which they formed a part. Their bases are often composed of till or boulder clay.'

The action of the glaciers, in following already defined depressions, is well seen at many points over the entire area of the province. Occasionally, two or more sets of striae occur, which often have courses at marked angles to each other.

Of these, the newer will almost invariably be noticed to run in the direction of a valley or, when near the coast, the course of some fiord or estuary. Excellent examples of this are seen in the vicinity of Sackville and Amherst, where the ice grooves and striae follow directly the depression between Bay Verte and the head of the Bay of Fundy, as also at Memramcook and Dorchester, where they follow the principal flexures of the Memramcook river. This peculiarity of direction is also noticed in both the adjoining provinces of Quebec and Nova Scotia. The older set of markings is, however, observed to keep a quite uniform direction, regardless of opposing hills, as if in many cases the propelling power of the glacier drove it resistlessly forward. If, then, we admit the existence of a widely extended ice sheet, which, in some parts of eastern Canada, appears to be quite clearly established, we must also admit a second and possibly a third ice era, during which local glaciers were shed from the height of land in whichever direction the most favourable outlet was presented, the course of which was largely affected by local conditions of configuration. In the northern area such evidences of local glaciers are visible in the striae which follow the outlines of the lower Restigouche and its tributaries. In Gaspé, also, local glaciers were undoubtedly shed in both directions from the tops of the Shickshock mountains, modified by the lower hill ranges which lie nearer the coast. In Nova Scotia, striae on the north side of the Cobequids point towards the shore of Northumberland strait, while on the south side they have a westward course in the line of the Minas basin and channel.

The divergence of river beds is conclusively proved at several points, though whether these changes were all due to causes subsequent to the glacial period, may be questioned. Thus, at the Grand falls of the St. John river, 225 miles from the mouth, the present channel below the pitch forms a wonderful gorge cut through the Silurian rocks for nearly a mile to a depth of over one hundred feet, the old channel being blocked at what is now the town of Grand Falls by a great accumulation of clay and other drift material. So, also, near its junction with the St. John, the old valley of the Tobique has been dammed, and a new channel excavated through Silurian beds for nearly the same distance. The time necessary to produce a gorge of such a length in the comparatively hard rocks of these localities must have been considerable. Whether such was the cause of the present outlet of the St. John river has not been conclusively proved, but appears highly probable, since huge dams of drift block up what appears to be an old outlet of the river in the direction of Manawagonish beach, a short distance west of its present mouth.

The views of Professor Hind (see Report of 1865) as to the glacial origin of many of the lake basins, do not, in all cases, seem to be fully sustained by the later investigations of Dr. Chalmers. The writer last named finds the depressions of some of the larger lakes in the southwestern part of the province to be pre-glacial, in the same way as the valley of the St. John river. The subsequent action of glaciers and glacial drift has, by heaping up moraines, modified existing conditions very greatly, either by forming entirely new basins, or changing very considerably those existing prior to the ice age. This peculiarity of morainic lake basins is well illustrated in many of the lakes of the St. Croix chain, along the boundary between New Brunswick and Maine.

Changes of level of the land are well shown by the presence of beds of marine or Leda clay at elevations, reaching, in some places, several hundred feet above the present sea level. This is also proved by the presence of old sea beaches at intervals along the coast of the Bay of Fundy, and now removed several miles from the existing shore line. That such changes of level have taken place in comparatively recent times is evidenced by the presence of tree stumps in the marshes about the upper part of this bay, now some twenty or thirty feet below high tide mark. These are found not only on the flats between Amherst and Sackville, along the shore, but in the several canals which have been cut for the purpose of improving the inner marsh. The partially submerged shell heaps on the coast of Charlotte county, which mark the sites of old Indian encampments, and presumably at one time removed beyond the action of the sea, also prove the gradual encroachment of the water, as well as the fact that these shell heaps are at a considerably lower level than when they were formed. On the other hand it is supposed by Professor Hind and others that the shores of the Gulf of St. Lawrence are now gradually rising, as is evidenced by the shoaling of the waters in the harbours and estuaries of the eastern coast, at the entrance to Miramichi harbour and the basin at Bathurst, since a marked difference in the depth of the water is now noted, as compared with the observations recorded within the last eighty or one hundred years. Some of these apparent changes of level may, to a certain extent, be due to the filling up of channels by sediment brought down by the rivers and redistributed by the action of the tides.

It might be supposed, by some persons, that the varied opinions expressed at different times concerning the true interpretation of the geological structure of the province would have a tendency to reflect somewhat unfavourably upon the character of the work done by the several observers in this field. A moment's consideration of the subject will, however, serve to correct this impression, since it must be remembered that, in the elucidation of the structure of any country, the discovery of new facts from time to time naturally leads to changes in the interpretation of the various problems presented.

The earliest workers had the misfortune also to labour at a time when the science of geology was, comparatively speaking, in its infancy. With the increase of our scientific knowledge enlarged views will be unfolded, while the peculiar bias pertaining to each individual must, of itself, ever give abundant cause for difference of opinion. In the study of any subject the object primarily to be attained should be the truth, sinking personal feeling for the general good.

PART III.

MINERAL RESOURCES.

The last report issued by the Geological Survey Department on the 'Mineral Resources of New Brunswick' was prepared by Dr. L. W. Bailey, and printed in 1899. It was very complete, and contained many details as to the early history and development of the principal mining areas. While enumerating the various minerals found in the province, the statement is made that 'of all these, with the exception of building stone, limestone, brick clay, and gypsum, only four substances have been as yet the basis of successful mining operations, viz., coal, iron, manganese, and albertite; and of these coal, alone, is at present actually worked.'

This is certainly not a very encouraging showing for the mineral resources of a province as large as New Brunswick; and while large sums of money have been spent in the search for economic minerals, and in the attempt to develop certain areas, it is to be regretted that a large amount of capital thus employed has been rashly, not to say foolishly, invested. In many cases conditions have been found which were unfavourable to the enterprise displayed by the investors; and in some cases such investment might have been prevented had a proper examination of the areas in question been made by experts familiar with the geological and mineralogical conditions of the localities.

In writing of the mineral resources of the province two courses may be pursued, either—(1) to indicate every mineral occurrence as a possible or even probable source of wealth to the investor, or, (2) to give a true estimate of the actual value of such occurrences, as estimated by expert opinion, of the various supposed mining areas; to indicate certain lines of mineral development which, if properly followed out, would tend to return a fair profit to the investor, and to discourage on the other hand, as far as possible, the investment of capital in localities or areas where the venture would in all probability yield no return, and would entail the loss of all the capital invested. For, while it is the custom for many persons to decry expert scientific opinion as to the value or otherwise of any particular mining area, it will generally be found, in actual practice or in the summing up of the final balance sheet, that more attention to such advice would have resulted in better financial returns. The scientific expert has acquired his knowledge by the study of both rocks and minerals in the field, over wide areas, and of the conditions governing mineral occurrences; and the information thus obtained is practically on the same lines as that which makes the opinion of a competent lawyer or physician, or in fact of any kind of professional worker, of practical value. This view of the case is too often lost sight of entirely.

In the following pages the latter of the two courses suggested will be followed as closely as possible, consistent with the general welfare of the mining industries of the province; and in so far as known by close observation and actual experience the possible value of each mineral occurrence will be indicated.

Generally speaking, the minerals of any country are associated with certain rock formations which have in process of time come under a certain orderly arrangement of geological formations, as for example certain coal deposits which, while belonging to the general system known as the Carboniferous, are found in actual mining to belong practically to one division of that system known everywhere as the Middle Coal formation, which is again divided into the Lower or Millstone grit-formation, and the Upper or Productive measures. As a rule, the large coal beds belong to the upper of these divisions, as will be seen by reference to workings in the adjoining province of Nova Scotia, although smaller seams are also found in the lower or Millstone-grit division. As far as our experience extends, however, the deposits of the lower, while showing at times a workable size, never reach the enormous dimensions which sometimes occur in the upper. Therefore we propose to give in brief a sketch of the several geological formations which have been recognized in the province from the study of its rocks during the last fifty years. It must be stated, however, that in some areas, owing to extreme alteration or other causes, the determination of the exact geological horizon is extremely difficult, and in some cases has not yet been definitely fixed.

The rock formations range from Pre-Cambrian as the oldest, to Triassic or the newest, excepting the Post-Tertiary, which comprises the sands, clay, and glacial drift generally. For some years it was supposed that the crystalline rocks about St. John, comprising areas of crystalline limestone, granite, granite-gneiss, etc., were the equivalents of the Laurentian of Quebec and Ontario, which are regarded as representing the oldest divisions in the world's history. A recent examination has, however, failed to establish this hypothesis, though they are among the oldest in the province. Most of the so-called granite-gneiss and other igneous rocks which occur with the limestones are intrusive in these, having cut them in every direction and changed them near the line of contact to a highly crystalline condition. At points farther removed from these contacts the limestones are bluer and more slaty, the colouring being due in some cases to finely disseminated graphite. The limestone is also associated with green, gray, and black slates and with beds of hard quartzite, which closely resemble portions of the recognized Cambrian rocks of this district.

As a source of mineral supply these rocks yield little beyond an unlimited amount of excellent limestone for burning, and from the associated slates a small quantity of graphite which is separated from the slaty shales and used locally. The lime industry has for many years been a very important one about the city of St. John, but of late years the production has fallen off considerably owing to the closing of the American market, through the imposition of a practically prohibitive tariff on the manufactured article. These limestones form a marked geological feature at the narrows of the St. John river about Indiantown, and in the area between the city and the shore of Kennebecasis bay to the north. The graphitic slates are well seen near the Suspension bridge over the river in the west part of the city.

The Pre-Cambrian rocks of the province also comprise what was formerly described under the term Huronian, of which three divisions were made. These were found to underlie, or were supposed to underlie, the fossiliferous Cambrian slates and quartzites, the lowest member of which has been styled the 'Etcheminian' formation, in the basal beds of which occur pebbles of an underlying series of ingeous rocks; though a part of what was once called Huronian, Coldbrook, has recently been regarded as possibly the lower member of the Cambrian series.

The Huronian, as a whole, consists of schists, felsites ,diabase, etc., the thickness of which cannot be determined since the series is essentially of igneous origin throughout. In the early reports on the geology of the province there were included in this series large areas of igneous rocks which have lately been found to be comparatively recent, as in the case of the gabbros near St. Stephen, with which occur the nickel ores of that place; and certain diabase rocks of Letite and other places in Charlotte county, which contain small quantities of economic minerals such as copper, galena, pyrite, etc. These have been developed to a small extent; but so far as known do not occur in large quantity.

In the northern part of the province there are large areas of crystalline rocks which have been assigned to the Pre-Cambrian, and may belong to the Huronian system. As there is no positive means of determining this question as yet, owing to the fact that the overlying rocks, though presumably of Cambrian age in part, have not yielded fossils to any extent, the age of the formation, which consists largely of igneous rocks such as felsites, diorites, and certain granitic masses, must be regarded to some extent as an open question. In some respects these closely resemble rocks of recognized Pre-Cambrian age near the coast east of St. John, which are there overlaid by fossiliferous Cambrian sediments.

The Cambrian rocks occur in well-defined areas as a series. Their age has been clearly demonstrated by the contained fossils, which have been studied in great detail by Dr. G. F. Matthew of St. John. They are well exposed about the city of St. John and form areas of considerable extent eastward, where they rest upon a great series of schists, felsites and other, generally speaking, igneous rocks, (all in a high state of alteration), which form the lofty ridges extending from St. John city into Albert county. The Cambrian rocks are usually slates, grey, green, and black in colour, with which are bands of conglomerate, quartzite and limestone. The slates are in places highly altered, thrown into folds and cut by quartz veins, with numerous faults and occasional intrusive masses of diorite. In age, they are apparently the equivalents of much of the gold-bearing series of Nova Scotia, but up to the present time no attempts to find gold in this New Brunswick series appear to have been made, unless indeed some of the quartz-veined slates of northern New Brunswick are a part of this system. Even here the search for gold appears to be confined to washing the sands from some of the brooks in the district. Small quartz veins abound in these northern slates, but no well-defined leads were seen in all our travels through this portion of the province.

The lowest fossiliferous division of the Cambrian appears to be a series of red and purple slates, conglomerates, and quartzite, which are seen about St. John city and to the eastward for some miles, occurring along the flanks of ridges of igneous rocks. This part of the system can generally be readily recognized. In the northern part of the province it is probable that rocks of this system occur in northern York, and form portions of the ridge of altered slates which crosses the province, appearing along the upper waters of the Miramichi river, and crossing the Nipisiguit river, where it is covered over by limestones and slates of the Upper Silurian formations.

The Cambro-Silurian rocks, which include the formations between the Cambrian and the Upper Silurian, are found at a number of places on both sides of the great Carboniferous central basin. Though not often fossiliferous, organic remains have been obtained at several points around the northern rim, as at Tetagouche on Chaleur bay, and on the Becaguimec in the western part. In the southern part of the province they are not so readily recognized, and large areas which were at one time placed in this group, provisionally, have since been assigned to the Upper Silurian. Of the Upper Silurian, or Silurian proper, large areas are known both in the southern and northern portions, where the great area between the Tobique and Nipisiguit rivers on the south and the Restigouche on the north are of this age, consisting largely of slates and limestones with occasional masses of intrusive igneous rocks. As a rule this formation is poor in economic minerals. The iron mines of Carleton, however, occur in these slates, and in southern Charlotte county they are much broken up by intrusive masses with which are small quantities of the ores of copper, nickel and galena. These form a soil of great value for agriculture, and are covered in the northern part by heavy forests of spruce and hardwood.

The Devonian rocks occur in considerable areas in the southern part of the province both to the east and west of St. John, and in the northern part overlying the Silurian. They contain quantities of fossil plants by which their horizon can be clearly determined, as also by their well established position between Silurian and Lower Carboniferous formations. In southern New Brunswick the system as a whole is divided into five groups, the uppermost of which is the Perry sandstone division, traceable eastward across the lower St. Croix river from the state of Maine, and extending at intervals for some miles east of St. John along the valley of the Kennebecasis river. These rocks were in the published map of the province, coloured as Lower Carboniferous, but the recent work done on these rocks has clearly shown them to belong to an older system. Another group of slates or shales known as the Albert shales, found in Albert and Westmorland counties, was also at one time regarded as belonging to the Lower Carboniferous division, but has, since the publication of the geological map of that area, been transferred to the Upper Devonian on good grounds. With this group is found the albertite and the bituminous shales now being exploited for petroleum. The remaining divisions of this system, comprising the Mispeck, Cordaite, Dadoxylon and Bloomsbury groups, include a great thickness of shales, sandstones and conglomerates, which often assume a schistose structure owing to alteration, and are penetrated by masses of igneous rocks at many points throughout their distribution.

The Carboniferous rocks are divisible into three groups, viz., the Lower, the Middle including the Millstone grit formation only, and the Upper or Permo-Carboniferous, which is found at intervals along the coast of the Gulf of St. Lawrence and Northumberland strait.

The principal minerals of the lower division are manganese and gypsum, while salt springs occur at several places.

The Millstone-grit division carries the coal-seams which outcrop at a number of points around the great central basin as well as in the interior. These have been worked to a limited extent for many years. The rocks are brown and grey shales and sandstones of purple and green-grey shades with occasional conglomerates, especially near the base. The principal quarries of building and grindstones occur in this formation, and beds of fire-clay sometimes accompany the coal seams.

The Upper or Permo-Carboniferous contains beds of brown freestone, which are worked at several points such as Sackville and Wood point where quarries of excellent stone are quarried. Thin seams of coal also occur, but these are of no economic value.

The Triassic formation occurs at a few points only along the north side of the Bay of Fundy. It consists of isolated outcrops of soft red sandstone and contains no minerals of economic importance. On the west side of Grand Manan island there is a great ridge of basalt which extends along its whole length and which sometimes contains traces of native copper similar to that found in the rocks of the North Mountain range of Nova Scotia.

Great ridges and masses of granite, both red and grey, are found both in the northern and southern portions of the province. These are comparatively recent, cutting formations as new as the Devonian. They are generally massive rocks, but sometimes a gneissic structure has been developed by pressure. Granites occur in connexion with all the formations from the Pre-Cambrian upward. They furnish large quantities of stone for building or monumental work, but rarely carry ores or minerals of value.

The Post-Tertiary or Pleistocene is the newest in the geological scale. It contains the peat bogs which are very extensive, the clays, sands and gravels valuable for bricks, pottery and for road material or for cement walls, and the deposits of Tripoli or infusorial earth and shell-marl which are found in a number of lakes in the southern part of the province. The mineral paints and the deposits of bog manganese or wad and of bog iron ore also belong to this formation, and have been utilized to some extent.

ECONOMIC GEOLOGY.

The ores comprise iron, manganese, copper, galena, silver, antimony, nickel and gold. Of these several have been mined quite extensively from time to time.

IRON.

The ores of iron comprise magnetite, hematite, specular ore and limonite or bog-iron. They are all found at widely separated points, are sometimes of good quality, and have been worked at intervals for nearly fifty years.

Hematite ores occur in beds of large size, interstratified with red and green slates, at several points in Carleton county. They have been known for more than sixty years and a blast furnace was erected as early as 1848 with a capacity of seven tons a day, a second furnace with a daily capacity of five tons being erected in 1863. These furnaces were in operation for some years, using charcoal for fuel, but the isolated position of the plant, at that time without railway communication nearer than some ten miles, interfered to some extent with the disposal of the output and the bringing in of supplies.

The ore is what may be called low-grade. It has also a considerable percentage of phosphorus and a high percentage of manganese as well as of silica. Methods of mining, handling, and of smelting have, however, changed very greatly within the last thirty years, while the demand for a workable ore of iron has increased so that it is possible that, by new processes and enlarged plant, combined with cheaper fuel, the disasters of former years may be changed and a profit from a renewed industry result, under proper management. No analyses of these ores made by this department are available, but several made in England, and furnished to Dr. Hind by Mr. Norris Best, the then manager, may be given as well representing their quality. The analyses are of eight samples, but the exact localities of these are not known.

—	1.	2.	3.	4.	5.	6.	7.	8.
Perox. iron	49·357	47·858	39·285	67·857	42·587	27·143	50·000	35·714
Prot. "	1·412	2·140	1·140	1·070	....	trace.	2·400	5·100
Alumina	6·200	3·924	3·116	2·004	6·412	10·742	6.114	5·076
Oxide. mang	4·784	6·110	5·872	0·976	2·140	5·172	3·742	6·840
Perox. "	.....	.....	.....	.....	8·740	.....	.....	.....
Lime	2·014	1·004	1·120	0·887	1·074	5·964	1·146	0·762
Magnesia	3·911	5·016	4·602	2·940	5·107	2·057	4·072	4·216
Potash	0·886	0·972	0·702	0·744	0·217	0·884	0·214	0·887
Soda	0·692	0·671	0·512	0·631	0·202	0·772	0·216	0·642
Sulph. acid	0·798	0·596	1·274	0·588	0·977	0·842	0·572	0·764
Phos. "	1·324	0·977	1·389	0·064	0·880	1·924	1·062	1·762
Silica	22·021	16·842	25·964	5·630	22·420	34·214	19·842	25·600
Car. acid and water	7·621	13·890	14·964	5·609	8·974	10·286	10·630	12·673
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000
Metal. iron	34·867	35·147	28·377	48·323	30·000	19·000	36·848	28·927

Mean of the eight .... 32·683

The principal ore beds are situated about six miles northwest of Woodstock. They have been described in the report for 1874, and their positions indicated on the accompanying map of the district. They occur in a number of beds which range in thickness from one to fifteen feet. The principal occurrences are at Moody hill, Iron Ore hill, Maple hill, and at Jacksontown, all on the west side of the St. John river. Other outcrops on the east side of the river are at Pole hill; near the forks of the Becaguimec river; and near Glassville. It will be seen from the above assays that the percentage of iron is not large and the sulphur and phosphorus contents are high as well as the silica. Yet during the process of manufacture of the pig it was claimed that an iron of good commercial value was produced which found a ready sale. During the last period of working a considerable quantity of bog iron ore from the Maugerville deposit a few miles below Fredericton on the north side of the St. John river was mixed with the hematites of the district. No work has been done on these irons for some years, the necessity of building a modern plant, together with the lean character of the ores generally and the remoteness of a fuel supply other than charcoal, which can still readily be obtained, hampering investment. It might be desirable to have a fresh series of analyses made from carefully selected samples to see if certain beds do not contain sufficient iron for commercial working.

In the altered Devonian rocks of the southern part of the province small quantities of iron, generally of the specular variety, are found. Of these apparently the most abundant are situated at West beach and near the mouth of Black river a few miles east of St. John. An examination of these ores during the past season by Mr. J. A. Robert shows that they occur for the most part in purple schistose slates. They are intimately associated with quartz veins and are not sufficiently concentrated to be profitably extracted, and no large ore-body was seen at either of these localities. The ores of West beach are more hematitic in character, but are also intersected with quartz and mixed with specular ore. Some years ago a small quantity was mined from this area and sent to the iron works located at Coldbrook, about three miles north of St. John city on the line of the Intercolonial railway, but the results of the tests made have not been published. The attempted development was not, apparently, successful, as no further work has been done at either of these places.

In Charlotte county, and in St. John west of Musquash harbour, similar occurrences of specular and hematitic ores have been recognized in altered Devonian rocks, but nothing of economic value has been found. Near the post road, about two miles west of the village of Lepreau, a large amount of money has been spent, principally in boring, to find a body of magnetite which was located several years ago by a Swedish expert with the magnetometer. Although the instrument is said to have located a very large body or lens of this ore, subsequent attempts to find it with a diamond drill were unsuccessful though the holes were bored at several angles which were supposed would strike the ore mass, and were continued in some cases to over 900 feet. In none of these, in so far as can be learned, was any ore found, with the exception of one small vein which was traversed, and which is probably the downward extension of a small (one-inch) vein seen at the surface. Analysis of the ore made in this Department shows the quality to be good, but the amount is too limited to be of economic value. The rocks are mostly hornblende schists, cut by masses of diorite, and small grains of ore are disseminated through the rock mass. Work has been suspended at this location.

On Deer island also a small vein of ore has been reported for a number of years. It consists of magnetite mixed with diabase, but the size of the vein is too small to be worked. So far as known no body of iron ore has been found in the southern part of the province with the exception of the bog ore at Maugerville below Fredericton, where a deposit occurs in a fairly continuous bed extending along the north side of the river for several miles with a breadth of one-half to three-fourths of a mile. The ore occurs here in the soil forming flattened aggregations from six to twelve inches in diameter though sometimes of larger size. The deposit is the most extensive and valuable yet found in the province and was mined some years ago and sent to the Woodstock furnaces. A similar deposit is found at Burton on the south side of the river, but the extent of this has not yet been ascertained. It has been described by Dr. R. Chalmers in the Survey Report for 1882-84, p. 99.

Other occurrences of iron are found in connexion with the granites near St. George as small veins of specular ore cutting that rock; as nodules of hematite in slates on Coal creek at the head of Grand lake; as veins of siderite in limestone and slates at the north end of Grand Manan island; as bog iron on the Southwest Miramichi near the forks of the Clearwater; at Tracadie; in the settlements of Queensbury and Beaver Dam in York county; as small veins of magnetite in slates on the Clarendon road, six miles west of Gaspereau station on the Canadian Pacific, associated with diabase rocks; as hematite in beds of small but unknown extent in the slates near Oak mountain southwest of Benton: and as loose pieces on Peabody farm about two miles south of Woodstock. These last may have been derived from the ore beds near that town. In none of these localities is the quantity, so far as can be ascertained, of economic importance.

At present the largest known area of iron ore yet found in the province is located near the mouth of the Nipisiguit river about twenty-two miles from the town of Bathurst, and near the junction of a small stream known as Austin brook, about one mile above the head of the Grand falls. The rocks are altered slates, in part schistose, cut by masses of green diabase and the ore is a magnetite occurring in a large mass extending back from the river to the north for about two miles, with an exposed width in places of thirty to forty feet. Quite recently another body of similar ore was found in the vicinity. The quantity of ore in the whole deposit is very large. It is distant from the Intercolonial at Red Pine station about nine miles, but a branch line could be built at comparatively small cost. The assays of the ore in this Department are as under:—

Analyses of five samples from the Nipisiguit Iron Deposit.

Nos. 1 and 2. From bluff behind camp near Nipisiguit river.
No. 3. From northeast corner, one mile back from river.
No. 4. Bluff one-quarter mile back from camp on large outcrop.
No. 5. Second large outcrop east of camp.

	1.	2.	3.	4.	5
Fe. metallic	55·36	51·20	46·00	48·30	59·20
Mn	0·44	0·32	2·17	0·94	1·62
Silica insol.	15·50	18·20	21·60	26·40	9·00
Phos	0·939	1·25	0·923	0·43	0·959

Laboratory of Geological Survey, November, 1906.

M. F. Connor.

Analysis of two samples from new area south of river.

	Linde-man.	Twin Tree I.M Co.
Insoluble	31·00	14·00
Metallic iron	43·20	56·60
Manganese	1·15	0·90
Phos	0·82	0·68

November 27, 1906.

M. F. Connor,
Analyst.

The average of fourteen analyses, by the Dominion Steel Company of Cape Breton, from different portions of the deposit gave:—

Iron	50·85
Manganese	1·35
Phosphorus	0·788
Silica	17·8

The area, opened by trenching, shows fairly well at the surface, and has recently been proved in depth. In places near the contact with the intrusive masses there is a small amount of iron pyrite, but otherwise the ore appears to be almost free from sulphur, and if the expense of opening and getting to the railway is not too great the deposit should be economically valuable. Boring with a diamond drill has shown the iron ore to have a thickness of over 300 feet in one of the holes.

COPPER.

Copper is widely disseminated in the southern part of the province, occurring in both the sedimentary and igneous rocks, especially near the coast of the Bay of Fundy. It occurs in several forms such as the oxide (cuprite), sulphides (copper pyrite, &c.) and carbonate (malachite, &c.). Native copper also is found in small quantities in certain of the trap rocks of Grand Manan island, similar in character to the deposits at Cape D'Or and the North Mountain range in Nova Scotia.

The ore most widely distributed is chalcopyrite. It is found in connexion with felsites, diabase and other igneous rocks at a number of places, but usually in small quantities. Especially is this the case with the series of igneous rocks, many of which are altered to the schistose slate, which extends from the islands of Passamaquoddy bay in the southwest part of Charlotte county eastward to Albert county. These rocks, while largely of the character of intrusives, have been so altered by pressure, among other things, that they have sometimes assumed the form of gneiss and schist, as have also the containing slates, resembling in this respect certain Pre-Cambrian rocks of the Huronian series. The intrusion of these igneous rocks into the slates and limestone is clearly seen at a number of points.

In certain areas along this coast these copper bearing rocks present some resemblance to the so-called copper bearing series of eastern Quebec. They are, however, in large part, of an entirely different horizon, especially in the western part of the area, though the presence of the copper ores may be due to the same general causes in both series.

A number of these copper deposits along the south coast of the province were opened some forty-five to fifty years ago, and large sums of money have been spent in a vain attempt to secure profitable returns from their development. It is perhaps not too much to say that of all the copper mines found in this group in the southern part of the province none have proved remunerative and, with the exception of one in Letite, all have long since been abandoned. The Letite mine, which was closed down for nearly forty years, reopened about five years ago.

Two causes seem to be against the profitable working of these deposits. In most of the occurrences the ore is a pyrite or pyrrhotite, occurring with quartz and a small quantity of calcite in irregular bunches. With this is often associated small quantities of chalcopyrite, but in no observed case is either the quantity or quality of the ore mass sufficient to warrant the expenditure of a large amount of capital in development. The usual statement of miners that the quality is sure to improve in depth is unfounded and certainly does not apply to these deposits so far as they have been worked. In some cases, as on Adams and Simpson islands, the quality of the ore (erubescite or peacock ore) is all that could be desired, and attempts to mine these have been made from time to time, splendid samples being obtained, but in these cases there appears to be no well defined body, the deposits being bunchy or pockety. The same remark applies also to much of the chalcopyrite. It frequently occurs near the contact of diabase with slaty rocks or felsites or along some small line of fault, and in quantity varies constantly, sometimes almost dying out entirely and sometimes reaching a thickness of some inches, but nowhere, in all this western district, can there yet be said to be a deposit of size and richness that can be worked at a profit.

The Simpson Island deposit at one time promised to be a valuable one, judging from the character of the ore extracted. This was largely a dark-grey copper sulphide which by exposure on the beach assumed the conditions of a pale green carbonate. The original location was on a vein of this ore below highwater mark, but owing to the impossibility of keeping the workings clear of water a shaft was sunk inland a short distance to intersect the vein. This attempt was not successful; though several small veins or stringers of the ore were found they were all too small to be profitably worked. The rocks of this island, like those of Adams island, are purple and green slates apparently of Upper Silurian age cut by green diabase, the ore occurring near the contact.

These dark-green, greyish and purple slates in places are altered to schists and cut by masses of green schistose diorite. They extend into Letite peninsula where copper mining has been carried on at intervals for more than half a century. Here the old Letite and the Wheal Louisiana mine were located, and shafts were sunk forty-five years ago to a depth of over 100 feet with drifts along the course of the supposed vein, in which the ore found was chiefly small quantities of pyrite and pyrrhotite with but a small showing of chalcopyrite so that the mining was abandoned. Since the opening of this Louisiana mine several years ago the old shaft has been carried down to a depth of over 300 feet, apparently following a line of fault or contact between slates and diabase. The ore from this mine is largely a pyrite mixed with quartz and some calcite, the former in small quantity, and occasionally with a small percentage of chalcopyrite. The width of the so-called vein varies from one inch to over a foot, but the proportion of ore to the gangue is small throughout and so far as worked the conditions do not seem to greatly improve on those found in the original mine. The enlargements in this deposit may be due to small slips along the line of the fault forming a lens shaped structure.

This pyritous character is found in all the mines examined on the coast west of Martin head in St. John county, the chalcopyrite being usually in small quantity mixed with pyrite or pyrrhotite; but east of this place, at what was once known as the 'Vernon mine' and at others in western Albert county, the character of the ore is somewhat different. Bornite occurs in small quantity disseminated through quartz veins associated with calcite or chlorite. The whole series is intersected by diabase dikes and the ores are usually found near the contacts of these with the slates or schists. Fine specimens of ore can be found here but attempts to mine, some forty years ago, were not attended with success, while the resumption of mining at this place five years ago resulted in the expenditure of considerable capital, without profitable returns to the stockholders.

The deposits worked in the neighbourhood of the Upper Salmon river in Albert county have long since been abandoned. While excellent samples are obtained at a number of places it has been found practically impossible to locate any well-defined lode of ore which would give profitable returns from their exploitation.

One of the largest copper mines, so far as expenditure is concerned, is a few miles to the northeast of Dorchester. It was first opened in 1882-3 and having been sold to an American company at a large figure was worked for several years at a loss, when it was abandoned. After being idle for some time it was acquired about six years ago by another company by which a plant for crushing the rock and contained ore and separating by electrolysis was erected at large expense. This was found too costly in operating to be profitable, and the mine was again closed about three years ago, since which time it has been idle.

This mine is located in the lower part of the Millstone-grit formation, the rocks being greyish grits and fine conglomerates. In places plant remains are quite abundant and the organic matter of these has thrown down a deposit of copper from solution—apparently during the period of formation, which now exists in the form of carbonate, surrounding the plant stems which in places have been changed to coaly matter. Beautiful specimens can be obtained, but the quantity is limited. It has been stated that the sandstone itself carries from three to five per cent of grey copper ore throughout the mass, and that by crushing the rock this contained ore can be separated by electrolysis. The aspect of the rock, however, does not warrant the statement that such a percentage of copper exists, and although a large amount of money has been spent in the mining of the plant remains, and of the rock itself, which have been treated in an expensive plant, the financial loss from such treatment has been very large.

The mines are situated along the crest of a ridge of the grit which has been opened for a mile or more. At the northern end of this ridge a shaft was sunk in 1884 to a depth of about 100 feet; it passed through the grey grit into a bed of red argillaceous marl such as is found on the streams adjacent and along the roads. The disseminated ore in the sandstone is visible only by the aid of a magnifying lens. It seems scarcely possible that by any known process such a small percentage of copper can be profitably extracted, and certainly the results thus far obtained have been most discouraging to the investors.

Indications of the presence of similar ores are found at a number of places along the shore of the estuaries to the south, and also near the roads in the direction of Sackville. In Nova Scotia similar ores occur in the area north of the Cobequid mountains and unsuccessful attempts to mine these have been made in that province for many years.

Many years ago a similar deposit was found at the mouth of the Nipisiguit river near Bathurst. The remains of a fossil tree were found embedded in a reddish sandstone and shale, upon which green carbonate had been deposited, but with the removal of the fossil plants the copper was exhausted.

Among areas in the western part of the province may be mentioned that of Bull creek about three miles south of the town of Woodstock in Carleton county. Here, in a coarse intrusive grey granite, small veins of quartz occur carrying traces of pyrite and chalcopyrite. The ore is like that on the coast of Charlotte county, and though attempts to mine it have been made from time to time, resulting in the expenditure of much capital, all such efforts have been unprofitable, owing to the very limited amount of ore contained in the area.

In the area to the north of Bathurst are several small streams flowing into Chaleur bay, where boulders of copper-bearing rock have been observed for many years, but as the country is generally densely wooded as well as partly drift-covered, the location of the ore body has never been found. The character of this district renders prospecting very difficult, and if any such deposit should ever be found it will probably be by mere accident. The rocks are slates and occasional limestones with masses of igneous rocks such as felsites, diabase and granite, most of which are more recent than the rocks with which they are associated.

A new locality for copper was seen last season on Jordan mountain in a dike of reddish felsite carrying a small proportion of greyish ore. The felsite cuts a greyish diabase and in one place has a breadth of eight feet, showing copper stains through the larger part of the mass. A small shaft has been sunk, but the showing of ore is not large and the actual value cannot yet be determined. Its occurrence is similar to the felsite ores of southern Charlotte.

NICKEL.

A deposit of nickeliferous pyrrhotite has been known for some years near the town of St. Stephen. The ore body is irregular, occurring apparently as pockety masses near the contact of altered slates and masses of a green-grey gabbro which are intrusive in the slates. Formerly it was supposed that these rocks were among the most ancient in the province. It now appears that the slaty portion is altered Upper Silurian, while the gabbro is newer. Their similarity to the nickel bearing rocks of the Sudbury district is not proven, since the latter are of Huronian age. An examination of the deposit near St. Stephen was made in 1903, in order to ascertain the actual economic value of this mass.

The result of the examination showed that the deposit of nickeliferous pyrrhotite occurred as a contact pockety mass for the most part in an intrusive gabbro which cuts Upper Silurian slates; that the deposit is limited in extent and that the percentage of nickel, being less than two per cent, is too low to be profitably extracted by methods now in use, and that no improvement in character could be found in any of the occurrences of the ore in the vicinity. In the Letite mine small amounts of nickel have also been recognized in the pyrrhotite, but here the amount of the ore itself is too insignificant to render the deposit commercially valuable. Assays of the St. Stephen ore, made in this Department, gave:—

Nickel	1·72
Cobalt	0·16
Copper	0·31

Assays of selected samples from both the Todd and Carroll mines gave Mr. M. F. Connor of the assay office, nickel 1·38; cobalt, 0·21.

It would seem from these assays, which fairly represent the whole of the output, that the percentage of nickel in the pyrrhotite is practically too low to permit of smelting by ordinary methods employed at Sudbury. If, however, a process of concentration could be installed on the spot at an expense not too great for an apparently limited ore body, it is possible that a paying industry could be established, by shipping the resulting concentrates to the large works at Constable Hook, New Jersey, where the final separation and refining could be effected. It is as yet, however, a question whether the quantity of ore in sight is sufficient to warrant the expense necessary for the erection of such a plant.

ANTIMONY.

Antimony in Canada is a somewhat rare mineral. With the exception of the deposits which occur in Hants county, Nova Scotia, and which have been worked intermittently for some years, that at Prince William, situated about twenty-five miles west of Fredericton, is the most available at present. In the province of Quebec the mineral also occurs in the Eastern Townships in South Ham, but no work has been done at this place for some years.

The discovery of this mineral in the slates and quartzites of York county at Prince William was made some forty-five years ago, the ore occurring as stibnite or sulphide of antimony. Masses of intrusive rock, granite and diabase occur in the vicinity and have led to local alteration of the strata, with the production of quartz veins in which the mineral occurs. Some of these veins are mere strings of quartz, while in places they reach a thickness of several feet. Native antimony also is present in small quantity.

The mining of these ores and their reduction in a furnace to metallic antimony was carried on at this place for some years, an extensive plant having been erected by the Lake George Antimony Company. The smelting was discontinued after several years trial, in which it would appear that the general results were not very profitable, and afterwards the ore mined was shipped in the crude state. In 1883 it is said that ninety men were employed, with a resulting shipment of twenty-nine tons, the shaft being sunk to a depth of 300 feet. Work was finally abandoned in 1890.

This ore apparently occurs as contact deposits or pockets, associated with some one of the intrusive masses. Whether a system of diamond drill borings would tend to locate other deposits at this locality is a matter for future testing under proper direction. The quality of the ore taken out is excellent, the percentage of the antimony as per analyses made by Dr. W. W. Bailey being as follows; from three samples:—

Antimony	68·91	70·1	69·00
Sulphur	28·86	28·84	27·28
Iron	0·85	·0	0·85
Gangue	0·81	1·50	1·50
	99·50	100·00	98·63

During the present year, 1907, work has again been resumed on this property and a considerable quantity of good ore has already been extracted. The prospects of successful development are reported as very favourable.

LEAD AND SILVER.

Veins of galena containing a small percentage of silver are found at a number of places both in the northern and southern parts of the province, and in rocks of widely differing character. Where tested, however, the results have been unsatisfactory.

In Charlotte county small veins of quartz, occurring in connexion with diabase dikes that cut altered slates and limestone of Upper Silurian age, are found on Frye and Campobello islands, and on the estuary of the Magaguadavic river about two miles below St. George village. At none of these places does the ore occur in economic quantity, and the several attempts made at development have long since been abandoned.

In St. John county, near Frenchman creek, on the east side of Musquash harbour, a pit has been sunk to a depth of twenty-nine feet in a whitish dolomite in which small stringers of galena mixed with a yellow zinc blende are found. The amount of ore is insignificant, but an analysis by this Department showed 25·08 ounces silver per ton of 2,000 pounds. On the west side of the harbour a small vein that occurs with granitic rock contained 14·218 ounces silver to the ton. The thickness of the vein of white quartz at the latter place is from eight to twelve inches and the galena is mixed with chalcopyrite. The hardness of the rock and the small size of the vein are against its profitable development.

In Kings county small veins of galena of no value are found in the Lower Carboniferous limestone of Dickie mountain north of Norton, and near Wanamake's inn on Hammond river in Upham parish, occurring with chalcopyrite in quartz veins that cut diabase and felsitic rocks, the galena carrying 3·099 ounces silver to the ton. Near Quispamsis also, indications of galena with pyrite and blende occur in granite.

In Gloucester county argentiferous galena has been found in several places within a few miles of the town of Bathurst, viz., the Nigadu river, the north branch Elmtree river, and on Rocky brook, a branch of the Nipisiguit. Although considerable work has been done on the Nigadu and Elmtree deposits all mining was discontinued some years ago. The Nigadu workings were opened in 1879-80 and the percentage of silver as determined in the Survey laboratory was about five ounces to the ton. The ore from Elmtree gave an assay about seven ounces to the ton. In both cases the deposits are too small to be economically worked.

GOLD.

Various reports as to the occurrence of gold have been in circulation for many years, but so far as the examination of the rock formations has extended no well defined gold bearing district has yet been located. In Nova Scotia this mineral is found with quartz veins in the gold-bearing slates which have always been regarded as of Cambrian age; but while rocks of similar age occur at several points, more especially about St. John city, and for some miles to the east, that also carry quartz veins and are thrown into folds, their auriferous character has never been proved.

These characteristic Cambrian rocks of St. John are well defined in certain parts by an abundance of fossils, a feature which does not belong to the Nova Scotia gold bearing series. It is, therefore, impossible to correlate the series in the two provinces. The St. John deposits are evidently much thinner than those of Nova Scotia, and while they are cut by diorites or diabase at several points there are not the same well-defined anticlines or large quartz veins as in the adjacent province.

The other areas of supposed Cambrian rocks extend across the northern part of the province from the Maine boundary in York county nearly to Chaleur bay. These are largely black and grey slates with occasional tints of red, and in some respects resemble portions of the Sillery rocks of Quebec. They are in places intersected with small and gashy quartz veins, but though fairly well traversed over hundreds of miles they do not show well-defined veins of the mineral. These small veins are especially abundant on the Upper Miramichi waters. Masses of granite and diabase cut the slates of this area, but though numbers of quartz veins were broken up during the work in this district, no trace of gold was seen in any of them. There does not appear to be any well-defined reason, however, why in some portion of this slate area gold may not some day be discovered; but the district is difficult of access, being a perfect wilderness, and hard to traverse, so that a well conducted prospecting party has probably never been over large portions of the country. All the reports of gold have so far been from local panning along some of the brooks, and of some of these the gold found was apparently the result of 'salting.' Of this character, probably, was the reported finding of a gold field several years ago near the head of the Nashwaak.

Only in one case was gold in place obtained by washing by Dr. Chalmers of this Department. This was on the upper part of Campbell river (the Right Hand branch of the Tobique), although in the reports of Dr. Hind the presence of this metal is recorded from several points.

MANGANESE.

This mineral was mined many years ago to a considerable extent and became an important article of export. The principal deposit was at Markhamville where an ore of high grade was obtained which occured in pockety deposits, sometimes containing hundreds of tons of pyrolusite near the contact of Lower Carboniferous limestone with the Pre-Cambrian rocks of the so-called Coastal range, which includes large areas of igneous rocks. The limestone in which the ore occurs is usually greyish or buff coloured, with bands of shale, and the manganese (pyrolusite) occurs sometimes as veins with calcite, or as lenticular bodies in the limestone itself. The mines at Markhamville produced from 1868 to 1894, in which year the mining ceased, 25,024 tons, valued at $409,203. No attempts, so far as can be learned, have since been made to locate deposits of this mineral along the line of contact.

Among other localities in which manganese has been found and worked to some extent may be mentioned the Glebe mine, three miles northeast of Markhamville, and seven miles from the Intercolonial railway at Sussex, the ore occurring as nodules or thin layers, associated at times with calcite. Several shafts and tunnels were opened

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but the actual mining continued for only a short time and was then abandoned. No returns of output are available.

On the east side of Jordan mountain, about seven miles northeast of Sussex, a deposit was discovered about twenty-five years ago. It is also a contact deposit occurring in Lower Carboniferous conglomerate near the contact of felsite and diabase, the conglomerate being made up of the débris of the underlying rocks. The ore is generally a fine-grained massive pyrolusite, but sometimes shows a crystalline structure. The main mass of the ore is near the base of the conglomerate and is exposed in a trench on the slope of the hill, but at the time of our visit last summer much of this trench was filled with débris. From Dr. Bailey's notes, however, we may assume that the ore extends for sixty-five feet with an average thickness of about six feet, and is apparently a lenticular mass conformable to the bedding rather than a true vein. Small stringers also occur penetrating the adjacent rock. The colour is generally iron-black or steel-grey with a dull lustre. Portions of the deposit appear to be low grade, while other portions are of fine quality. The following assays taken from Dr. Bailey's report are appended:—

Analysis by Prof. P. B. Wilson, Baltimore, Md. November 7, 1887.

Mang. bi-oxide	86·08
Metallic mang.	54·57
Iron oxide	0·87
Silica	2·86

Analysis by Dr. Otto Wirth, Pittsburg, Pa., November 22, 1887.

Metallic mang.	52·88
Iron	1·18
Silica	9·70
Phosphorus	0·014

Analysis by Pennsylvania Steel Company, December 12, 1887.

Manganese	57·37
Silica	0·23
Phosphorus	0·015
Sulphur	0·61

The ore was hauled by team to Sussex station, I.C.R., a distance of seven miles. Work has been suspended for some years, but a number of tons are on the ground awaiting shipment.

The deposits at Quaco head, one mile southwest of the village of St. Martin, on the Bay of Fundy, occur in Lower Carboniferous shale and limestone associated with conglomerate. The ore is chiefly pyrolusite, and the rocks are cut by dikes and masses of diabase. The strata are much disturbed and the ore is found in irregular veins of varying thickness and in nodules from an inch to several inches in diameter, the thickness of the ore-bearing bed being estimated at about thirty feet in places. Analysis of the ore by Dr. A. M. Comey shows for selected samples:—

	Compact Variety.	Porous Variety.
Manganese peroxide..	71·54	65·00
Ferric oxide..	2·19	1·75
Calcium..	trace	trace
Phosphorus..	0·02	0·04
Sulphur..	0·00	0·00
Insol-silicates..	8·37	6·66
Manganese..	58·20	57·15
Iron..	1·53	1·23

Dr. Bailey remarks on this deposit 'The ore-bearing rocks can be traced on the promontory at intervals for almost a mile, to a place where an opening has been made on the farm of Mr. Molaskey. On the north side of the head small scattered nodules of manganese ore are found in the gravel drift that lines that part of Quaco harbour and extends inland over the Lower Carboniferous rocks. They have doubtless been derived from the latter rocks during deposition of the gravel, in the same way that the red sandstone just mentioned obtained its manganese contents at an earlier date.' Like the rest of the manganese mining of this province work has here been discontinued for some years.

On a small deposit of this ore, found on the east side of Salisbury bay in Albert county, near the contact of Triassic and Lower Carboniferous rocks, some mining was done thirty years or more ago. In the vicinity of Elgin, on the north side of Gowland mountain, large pieces of good ore have been obtained on the surface, but the source of these has never yet been found. It probably is at or near the contact of the slates and conglomerate of the valley with igneous rocks of the mountain.

On the west side of Shepody mountain a deposit of considerable extent was discovered and worked many years ago. It is at the contact of Lower Carboniferous shales, limestone and conglomerates on the north side of the mountain along the road from Hopewell to Albert mines. The mining was begun in 1860 by a Mr. Steadman of Hopewell who drove an adit into the limestone for a distance of about 500 feet. The ore was the black oxide and of high grade, about 500 tons being reported as extracted. It was found both in veins and as beds, with an occasional thickness of five feet. Works were erected for the treatment of the ore on the ground, but owing to lack of capital, or lack of experience in its manipulation, were shortly after abandoned and the place has become a ruin. It is possible that further exploration on this line of contact would discover other deposits of the mineral.

The uncertainty of finding continuous beds of this ore militates against a persistent search. There is apparently no reason why the mineral should be confined to one portion of a contact between igneous rocks on the one side and Lower Carboniferous limestone on the other, especially where the ore occurrences are large and fairly continuous, but the expense of carrying on the exploration beyond the limit of the profitable areas has evidently been sufficient to deter investigation in many cases, even when such further exploration might have resulted in finding other and similar deposits.

The largest deposits of manganese in the province are of the variety known as wad or bog ore. This is more or less earthy and impure, occurring on the surface in beds of considerable extent at several points. Of these the largest at present known is in Albert county, at Dawson settlement, about five and a half miles northwest of Hillsborough. It is found principally on the north slope of a hill that rises from a small brook flowing into the Petitcodiac river. The upper part of this slope is wooded, but the lower portion is cleared, and when a thin covering of soil is removed an extensive deposit of a fine black powdery mineral is exposed covering the whole hillside. This has been proved in depth by boring and found to extend downward in places for twenty-five to thirty feet, the lower part sometimes being of a hard nature as if the mineral were in the solid condition. The estimated quantity of wad at this place is more than 170,000 tons. Analyses made by well known chemists give as the average of twelve samples:—

Metallic manganese	45·81
Metallic iron	9·95
Sulphur	0·03
Phosphorus	0·05
Silica	5·36

This ore is practically valueless for the uses to which pyrolusite is applied, and in its natural condition is of but small commercial importance. After trying in vain for some time to work the deposit, a scheme of briquetting was instituted which has aparently solved the problem of its utility. An extensive plant has been erected on the spot, the manganese powder is wheeled in to the dryer, then conveyed to the mixer, and then to the machines for briquetting, whence it comes out in the form of cylindrical blocks about two inches in diameter and the same in length, of sufficient cohesiveness to stand transport by rail to place of destination. The raw material in its dry state is difficult to manipulate as the fine powder is very penetrating and fills the surroundings with a smothering dust. The prepared blocks were shipped to iron works at Bridgeville, N.S., where they found a ready market during the time of operation. Owing to several causes, financial and legal, the works were closed down about five years ago and have not as yet been re-opened though the property has changed hands. Outcrops of similar ores are found along the course of the brook, but no attempts at developing these have apparently been made.

BITUMINOUS COAL.

The history of the New Brunswick coal-fields has been written so frequently that it scarcely seems necessary to reproduce it here, in any considerable length. As regards the geological aspect of the question, the rocks that make up the Carboniferous system of the province are divisible into three parts, viz., the Lower, comprising limestone, gypsum, red conglomerate, shale or marl and sandstone both grey and red; the Millstone-grit, comprising purple and grey shale and sandstone with conglomerate holding white quartz pebbles near the base, the formation containing thin seams of coal, workable in places, of which at least two have been recognized; and a series of soft red, sometimes greyish sandstones and shales similar to the rocks of Prince Edward Island, found in small areas along the east coast of the province bordering on the Gulf of St. Lawrence and Northumberland strait, belonging to the Upper or Permo-Carboniferous. The productive coal-measures of Nova Scotia which, with the Millstone-grit, form the Middle Carboniferous in that province, are not apparently represented in New Brunswick.

The Millstone-grit rocks occupy a large area, approximately not far from 10,000 square miles, of roughly triangular shape, with the base on the Gulf of St. Lawrence. At a number of places around the margin of the basin, as well as at points in the interior, outcrops of bituminous coal occur. To the northeast these are seen on the south side of Chaleur bay, at New Bandon and near Caraquet, where the thickness is from six to ten inches; also on the Dungarvon river, one of the branches of the Miramichi, the thickness of coal being from ten to twelve inches. North of Fredericton it outcrops on the

Taxis and Nashwaaksis rivers; to the southwest on the Yoho and Oromocto rivers, with a thickness of four to five inches only; but no boring has been made in these localities so far as is known to determine whether a lower or thicker seam does not occur. Going east along the southern margin it occurs on Mersereau brook the thickness not being definitely ascertained, but apparently about one foot, and farther east in Clones, on a small stream, two seams are reported which according to the notes of Dr. Matthew gave a thickness of about three feet. On a subsequent trial by boring this thickness was greatly reduced. On the east side of St. John river on Long creek, south of the Washademoak near Cole island, the seam outcrops with a thickness of about ten to twelve inches, but is a dirty coal.

In the interior of the basin the principal outcrops are about the head of Grand lake, and on the Coal branch, a stream in Kent county flowing into the Richibucto river. At Minto, which is the present name of the mining centre in the Grand Lake district, and the terminus of the railway from Norton on the Intercolonial, two seams are found, one of twenty to twenty-four inches, the second from six to ten inches. Sometimes these approach so closely as to be worked as one, the parting of shale being reduced to about three inches. In the report for 1872-3 the measurements of these seams at a number of outcrops are given. Since that date mining in this area has developed very much and the thickness of the seams worked can be better ascertained. The thickness of thirty inches is found at King's mine, and practically on several areas adjacent. In the report referred to a measurement of coal near the steamboat wharf on the lake, on McMahon's property, as seen in a stripping for a length of forty feet, also showed thirty inches of coal. In the report on 'Mineral Resources, Bailey, 1897,' mention is made of the property of Robert Cox on the Emigrant Settlement road, where there was measured thirty-three inches of coal in two seams separated by a six inch parting. The seam as measured in King's mine was in two parts, the upper of twenty-four inches, a parting of three inch shale and a lower seam of six inches.

At most of the mines in this vicinity, while probably the two seams occur, the parting evidently increases in thickness so that usually only the upper seam is worked, varying from eighteen to twenty inches of good coal. But even with this comparatively small seam it is possible to take out a large amount of coal when properly and economically mined. It is estimated at King's mine that the coal per acre from the thirty inch seam totals nearly 4,000 tons, the coal being entirely removed. This gives about 1,500 tons per foot of seam per acre in mining.

In the Coal Branch area the seam ranges from sixteen to eighteen inches, which is the one at present mined, while in a boring one mile north of Moncton sixteen inches were passed through. Farther south at Dunsinane a seam of eighteen to twenty inches outcrops on Stones brook which has been opened up by adits to a depth of about seventy feet on the dip of the seam, and a number of bore holes have been put down which showed the presence of two seams with the aggregate thickness of the seams at Minto. Preparations are now being made for a further test of this side basin at Dunsinane.

It will be seen, therefore, that what may be called the principal seam extends over a wide area. It does not necessarily follow, however, that its continuity is unbroken throughout this whole extent, since in the series of low undulations which affect the coal-bearing strata some portions of the coal have probably come to the surface and have been removed by denudation. This is seen at the borings recently made at Pockmouche near Caraquet, where the small seam on the shore reappears inland a few miles south, and was opened in a shallow pit, while in a boring a few hundred feet north to a depth of over 700 feet no trace of the coal was found. Here the drill apparently passed through the so-called coal meaures for about half the distance down, then through the Lower Carboniferous formation and penetrated the underlying Devonian for nearly 100 feet of grey sandstone, representing portions of the grey sandstones of that age so well exposed on the Gaspé coast to the north.

The thinness of the coal-bearing formation as a whole is also seen from the borings made at various points such as at Minto (Grand lake) where the underlying Devonian slates were met at a depth of 260 feet from the surface and in the boring at the Bridge at 211 feet, this hole being started at about sixty feet below the surface seam. The Devonian rocks apparently occur as a ridge without a covering of the Lower Carboniferous at this place. Another hole bored near the outcrop of the coal and about two miles west of this one, reached the slates at practically the same depth below the coal.

At other places the thickness of the formation varies somewhat. Thus in the boring at Cocagne in Kent county the Lower Carboniferous was reached at about 850 feet in so far as the borings can be determined. In this boring a seam of coal of four inches only was reported a few feet from the surface.

At Dunsinane the thickness of the Millstone grit is about 400 feet; at Chatham about 300 feet; at Caraquet about 400 feet; at Three-tree creek south of Fredericton about 300 feet, no coal being found here; and at Moncton in a boring about one mile north, or near where the new railway yard is located, a seam of sixteen to eighteen inches was struck at a depth of 609 feet underlaid by a band of coal and shale one foot thick, but no recognized base of the formation was reached, the hole being continued downward for only 140 feet farther. It will be seen therefore that the thickness of the so-called coal-formation in the province is quite thin, and that with the exception of the coals known as the 'surface seams' there is nothing as yet found to warrant the assumption that deeper lying seams exist.

For many years the coals exposed at the mines of Newcastle creek near Grand lake have been worked on a small scale. Until within the last five years when the railway was completed from Norton to Minto, where the principal mines are situated, the only means of transport to market was by woodboat on Grand lake in summer or by teams in winter to Fredericton, thirty miles distant. Up to that date no attempt appears to have been made at screening the output or at separating the slate and sulphur, the entire output being shipped to the market as run of mine. In addition to the original defects in the mining of the coal the methods of shipment necessitated the handling or shovelling from team to landing, then to barge, then the subsequent movement, until in all it was handled or shovelled and dumped six to eight times. As a consequence the coal was generally broken into small fragments, thoroughly mixed with dirt and other impurities and was universally regarded with disfavour for domestic consumption or as a producer of steam. With the advent of the railway a new era was inaugurated. Several of the mines were equipped with hoisting plants either by steam or by horse whim, the output was carefully screened and handled and inspected by an inspector appointed by the Intercolonial railway, and as a result the coal shipped to Norton station is of excellent quality, clean and bright, and furnishes a fuel for either domestic or steam purposes equal to any obtained from the Nova Scotia mines.

At present there are twenty-one companies or mine owners engaged in mining at Minto and vicinity. Of these, nine mine and ship their coal direct from the pit by railway with a minimum of handling, either to Norton or to Chipman, from which latter place it is shipped to St. John or Fredericton by schooner. The remaining twelve producers ship by water from the wharf on Grand lake by woodboat. This water shipment amounts annually to about 4,000 tons, is unscreened and handled in the old way, the coal being hauled to the landing in wagons, and consequently is unsatisfactory to the consumers. That sent by rail for the Intercolonial is screened, but a considerable portion of the rail coal is also shipped as run of mine. The value of the screened coal at Norton is $3 per ton; of the screenings the value is from 90 cents to $1.

The thickness of coal mined at King's pit, formerly Kennedy's, and known as 'Rapids coal,' is, as already stated, thirty inches, made up of two seams, an upper of twenty-four inches, a three inch shale parting, and a lower of six inches. The whole is extracted, and in the mining about two feet of the shale roof is taken out to ensure height in the drifts. The railway is extended to touch the openings, of which there are in all nine, along the outcrop, but of all these King's mine is the only one at present using steam for hoisting.

The thickness of the worked seam at the other pits on this line of outcrop varies, those at the southern end working only the upper seam which ranges from eighteen to twenty inches. It is possible that in these cases the shale parting has thickened so that the lower seam cannot be utilized, unless indeed it has disappeared entirely. In the vicinity of King's mine, at Walton's, the seam aggregates twenty-eight inches; of which eighteen are good coal; and the levels were in for 150 to 200 feet during last summer, 1906, the daily average output being about twenty-five tons. At Coakley's mines adjacent to the south the thickness is given as twenty-six to twenty-eight inches with a parting of six inches from the bottom; at McDonald's the thickness of coal is twenty to twenty-four inches of which twenty inches are good coal and two to four inches at bottom are slaty. The remainder of this group of mines work on a seam ranging from eighteen to twenty inches thick. It does not seem to be established whether there is a lower seam under this portion of the field.

At King's mine the levels in August were driven west from the bottom of the shaft which had a depth of thirty feet, to a distance of about 800 feet, with cross drifts every thirty-five feet. The average daily shipment is 120 tons or six cars of twenty tons each for say 300 days. This includes the screenings. The run of mine coal sells for $2.35, and the amount of screenings is about 35 per cent. The pay of the men is by the box raised, at 18 cents, nine boxes to the chaldron of one and half tons. The mines of this group work all the year.

The second group of mines includes those that work intermittently. In places the surface, when not more than nine feet deep, is removed and the underlying coal quarried out, but for a deeper cover this is unprofitable. The seam usually ranges from eighteen to twenty inches, and the mines are worked when there is demand for the coal or when the owner is not otherwise engaged. The mines of this group are scattered over a wide area, extending from Newcastle bridge, and New Zion on the Fredericton road on the west, to Flower cove on the shore of the lake. Another outcrop which is found on the Little river about ten miles west of Newcastle, with a thickness of about fourteen inches, has not been worked to any great extent. Details as to the thickness of the coals in this district are given in the report by Bailey and Matthew, 1872-73, in which the presence of the two seams is clearly indicated.

Prior to the opening of the railway to Minto the annual output rarely exceeded 10,000 tons of run of mines. With the improved plan of mining and facilities of shipment this has increased to between 40,000 and 50,000 tons for the year 1906, the amount in tons largely depending on the possibility of obtaining miners. Were men available the output could be largely increased, since there is practically an unlimited demand for the coal as now prepared for the market, and if a number of the principal mines could be brought under one management there would certainly be a marked improvement in many ways and a larger percentage of profits.

The only other place where coal-mining is now carried on in the province is at Beersville in Kent county. Here a seam of coal from sixteen to eighteen inches thick outcrops on the banks of the Coal branch, a tributary of the Richibucto river, the outcrops being about three miles apart on the stream. Mining on a small scale by the settlers was carried on here for some years and local supplies of coal were thus obtained, but about six years ago a company was formed to mine on the large scale, a branch railway of seven miles was built to connect with the Intercolonial at Adamsville, and the coal was gained in the regular way by adits and cross-drifts. Two of these have been driven, one to a depth of 1,300 feet, the other at the time of my visit (August, 1906) 700 feet with cross-drifts every twenty-five feet. The drifts are run in from the bank of the stream about twenty-five feet above water level and fifty feet from the top of the cliff, up which the coal is hoisted by a three horse whim which can raise a load of three tons up the incline to bank head, where it is loaded into cars for shipment by rail. The miners receive thirty-eight cents per box of 600 pounds for the mining, and in the period between March 1 and June 1, it is said that about 3,000 tons were raised in this way. The freight rate to Adamsville is forty cents per ton, and the value of the coal at the station is $3.10. The capping of the seam is a grey shale, about three and a half feet being removed in the mining; the underlying rock is a bed of fire-clay of two feet. The miners work in eight hour shifts of eight to ten men and mine on the average four boxes or 2,400 pounds per man. The price of the mining, therefore, is not very different from that at Minto. The coal splits readily into broad flakes, burns freely with a strong heat and makes steam rapidly. The output is not screened and the shipments to railway are run of mine. In character it resembles closely that from the Grand Lake mines.

At Dunsinane on the Intercolonial, about thirty miles southwest of Moncton, another coal basin occurs, separated from the southern margin of the main basin by ridges of Lower Carboniferous and in places by igneous rocks. On the south also a prominent ridge of Lower Carboniferous sediments is seen, and the width of the basin of coal rocks is about four miles. Near a small brook (Stones brook) the coal outcrops in a seam of eighteen to twenty inches which has been opened by several adits to a depth of about seventy-five feet, and a number of tons have been removed that resemble in character the coal from the Grand Lake basin. This, when carefully mined, gives satisfaction.

Some years ago a series of borings was made, with a diamond drill, in this small basin, one of which was carried down to a depth of 1,300 feet. In several of these holes two seams were cut, the upper as seen in the drifts, and a lower of somewhat variable thickness according to the logs, but which showed a tendency to approach the upper and form one seam as in the case of the seams at Minto. Borings to settle this point are now in contemplation and if the dip of the seams is constant their junction should be a short distance north of Shives siding, in which case a seam with a thickness of two and a half feet may be found. If at a depth not too great this should be workable, owing to its proximity to the railway.

In view of a further possible development of the coal industry in this province it is advisable that a systematic series of borings at well selected points should be made, as was recommended some thirty years ago, but only partially carried out. For while there is no likelihood of finding large seams like those of Nova Scotia, judging from the results obtained from the borings made at widely separated points, it is quite possible, with judicious management, to obtain an output of some thousands of tons of excellent fuel, which in view of the railway construction now contemplated, should be able to meet fairly well all local demands, both for locomotive and domestic consumption, as well as for the several factories located in St. John and Fredericton, which now consume large quantities of the slack or screened coal, as also of the run of mines output. The eastern part of the province would, however, probably continue to derive its coal supply to a large extent from the mines of Springhill which are but a few miles distant.

As regards the occurrence of anthracite to which allusion is frequently made, and which has been supposed to occur in quantity at Lepreau and at Musquash, it may be said that at neither of these localities is the fuel obtained of sufficient value as a coal to warrant the expenditure of further capital in its development. A large amount of money has already been expended at both these places, but the deposits are rather of the nature of a highly carbonaceous shale, and the so-called coal is a graphitic carbon yielding a high percentage of ash, (36 per cent) which remains after the carbonaceous matter is burned off, and this is accomplished only under a strong draft. At both places all work was abandoned many years ago, and the workings have fallen into decay. At Lepreau the so-called coal bed, which had a thickness of some four feet, was opened up by several shafts to a depth of 140 feet, while at Musquash a slope was sunk to a depth of over 300 feet without any improvement in the quality of the output. Several miles southwest of Musquash a number of holes were put down in this black shale with the same results.

An analysis of the coals from nine of the pits at Minto was furnished by Mr. W. H. Hunter, the present manager of the railway from Norton to Minto and is as follows:—

—	Connellsville, Pa.	Balkins.	Evans.	Kings.	Gibbons.	O'Leary.	Welton.	Coakley.	McDonald.	Kelly.
Moisture	1·10	0·60	0·80	0·60	0·58	0·72	0·65	0·74	0·67	0·6
Vol. matter....	32·75	36·94	36·54	35·36	33·90	57·28	33·85	34·56	37·13	35·8
Fixed carb.....	57·08	55·03	52·94	55·40	52·37	52·41	56·58	55·72	52·89	54·35
Ash.	9·07	7·43	9·68	8·64	13·14	9·59	8·92	8·98	9·31	9·25
Sulphur.......	·85	4·48	5·81	5·63	6·09	2·99	5·25	8·46	4·72	3·92

Analysis of Grand Lake (Minto) coal made in Department of Geological Survey, 1906. M. F. Connor.

Moisture..	0·46
Vol-Combustible..	35·40
Fixed carbon..	58·54
Ash..	5·60
	100·00
Sulphur..	2·97

Analysis of Dunsinane coal by Mason and Askwith, Halifax, N.S. Furnished by Mr. John White, from sample of No. 5 pit, 1900.

Vol. matter..	39·20
Fixed carbon..	55·60
Ash..	5·15
	100·00

Analysis of Dunsinane coal by Mr. M. F. Connor, Geological Survey, 1906.

Moisture	1·28
Vol. matter	34·18
Fixed carbon	49·06
Ash	15·48
	100·00
Sulphur	7·90

ALBERTITE AND BITUMINOUS SHALE.

A great body of peculiar brownish and dark grey shales occurs in Albert and Westmorland counties and has long been known under the name of 'Albert shale.' It can be traced across the former county from Elgin on the west through Baltimore and the Albert mines and across the Petitcodiac river to the vicinity of Dorchester. Westward it is also found in that part of Kings county south of the Kennebecasis valley, but here the amount of bituminous matter is much less than in the eastern portion. These shales of Albert and Westmorland are peculiar in carrying a large percentage of bitumen which can be extracted by a process of distillation, and some forty years ago works for the extraction of the contained petroleum were in operation at Baltimore with a certain amount of success until the discovery of the great oil-wells of Ontario and of the United States so reduced the price of the raw products that the manipulation of these shale beds was rendered unprofitable and the works were closed.

These shales came into marked prominence many years ago through the finding at Albert mines of a great body, in vein form, of the peculiar mineral known as albertite, at that time regarded as a true coal occurring under peculiar conditions. This supposition as to its coaly nature was, however, soon abandoned and the material was regarded as a highly altered pitch or bitumen. It was mined for more than twenty years and yielded in all over 200,000 tons, which from the high price obtained, over $20 per ton, rendered it for some years one of the great mineral assets of the province and a source of great profit to its fortunate owners. This vein was mined to a depth of about 1,300 feet and in length for about half a mile and was practically exhausted twenty-five years ago, the lower portion changing into a brecciated mass of shale cemented by the albertite and thinning out to a few inches, while at either end it also became so thin as to be unworkable. Though the deposit was practically a hardened bitumen or pitch but slight traces of petroleum were found throughout the whole period of mining.

The age of these rocks was for many years regarded as Lower Carboniferous. The detailed study of the relations of the shales to the recognized Lower Carboniferous formations, comprising limestones, gypsum and other rocks, proved them to be unconformably beneath these rocks and of late years they have been regarded by all who have recently studied these deposits as belonging to the upper part of the Devonian system.

The large vein of mineral has not entirely been worked out, and it is known that other occurrences of a like nature occur in this area, though probably not of such great size. Thus, in the course of mining, it was found that the main vein, which was the one followed, deflected from its somewhat east and west course to a southeast course about midway in the line of workings. But recently another vein, which at the surface has a thickness of about two feet, has been found starting from the point of deflection and following the general direction to the east. This small vein has been proved to some extent, but if it develops the same conditions which affected the main vein, which occasionally reached a thickness of nearly seventeen feet, it would seem desirable that its development should take place.

In the western part of the area at the Albert mines, also, several small veins are known to occur, with a thickness in places of one foot, which have been opened to a limited extent. These are probably spurs from the main vein, but their proximity to the mass of crystalline rocks of the Caledonia mountain to the west will limit their extension in this direction. It is, however, possible that some of these veins will increase in size at certain points so as to render their mining profitable.

The Albert shales themselves are of special interest from the amount of bituminous matter they contain throughout their whole extent. They have a thickness of over 1,000 feet, but the exact figures are difficult to ascertain owing to the presence of folds and faults. As a series they are highly inclined, sometimes reaching the vertical. A number of sections were made at various points during our investigations in 1876, both of the eastern area on the Memramcook river, at the Albert mines, and as far west as Elgin. The same broken character was observed throughout and the amount of bituminous matter contained in the whole body of shale is estimated at from fifteen to thirty gallons of petroleum per ton.

At many points throughout the shale belt are beds of a dark, black or grey shale especially rich in bituminous matter. This rock has a woody aspect, breaks with a conchoidal fracture and on fresh surfaces shows numerous black streaks resembling hardened pitch. It has been found to contain from fifty to sixty-three gallons of oil per ton for the dark brown varieties, while some of the greyish bands carry as much as eighty gallons as obtained by experimental distillation. The albertite itself yields over 100 gallons.

Of these rich shale bands at least five have been recognized, varying in thickness from one to five feet or even more. On the upper part of Turtle creek, in western Baltimore, the grey shale bands are found with a thickness up to seventeen and twenty feet according to measurements by Mr. W. Hall, late manager of the Spring Hill mines in Nova Scotia. Unfortunately it has up to the present been difficult to obtain definite data as to the actual economic value of these shales, but from the fact that splinters of this shale will readily kindle from the flame of a lighted match they are undoubtedly very rich in oil. The shale has a low specific gravity (1·50) and yields a large amount of gas of high candle power, burning with a strong yellow flame and with an intense heat.

In addition to the several varieties of oils which are obtainable from these oil-shales, the by-products are of considerable value, and should, in the manufacture, be a source of large profit. They include paraffin and other products such as naptha, benzole, aniline and sulphate of ammonia. As a steam producer it is claimed that the shales (oil-bands) give results equal to that obtained from high-grade coal either bituminous or anthracite, and though the percentage of ash is high its comparative freedom from sulphur, and the absence of clinker and slagging of the furnace bars, is such that the handling of the greater amount of ash is less troublesome than is the case with ordinary coals.

From tests made by the gas company at St. John the amount of gas obtained from the shale was 8,500 cubic feet per ton. Analyses of the shale bands have been made at the Standard Oil Company's works at Bergen point, with the following results:—the data obtained through the courtesy of Mr. M. Lodge, of Moncton, N.B.

Sample of the oil-shale from Baltimore.

Vol. carb. compounds	42·78
Fixed carb. compounds	17·45
Silica	20·88
Alumina	7·91
Iron	1·79
Calcium sulphate	7·56
Magnesia	1·11
Phos. acid	0·34
	99·82
Ash	39·70

Analysis of the grey and black shale of Baltimore by Ricketts and Banks, N.Y., 1893.

From the Grey bands—

Moisture	1·10	1·54
Vol. matter	45·32	51·22
Fixed carb	1·29	3·03
Ash	50·69	44·21
Sulphur	1·70	.....
	100·00	100·00

Analysis of the Black bands—

Moisture	0·36	0·64
Volatile	39·50	45·52
Fixed carb	3·00	5·05
Ash	56·10	48·79
Sulphur	1·04	.....
	100·00	100·00

From the known enormous extent of these highly bituminous shales, and their high percentage of bituminous matter, it would appear that if properly developed they should form one of the great mineral assets of the province. A comparison with some of the similar shales used for the manufacture of shale oil and by-products in Scotland, Belgium, France, New Zealand and Australia, shows that, taking the shale formations as a whole, the New Brunswick deposits are richer in bituminous matter than in any of those countries in so far as can be learned from obtainable data. In all these countries the shales are utilized on a very large scale.

Though no recent data as to the production of oil shale and oil are to hand for the Scotch industry, information obtained from Boverton Redwood's volume on Petroleum, 1896, furnishes the returns as late as 1894. These figures may be here given as bearing on the general question of the utilization of the New Brunswick shale deposits and as showing the enormous development the industry in Scotland has attained.

In Scotland alone, for 1894, the output of shale was 1,986,383 tons.

The average output for the ten years preceding was 1,888,339 tons.

The annual output varies somewhat from year to year. The specific gravity of the shale is about 1·75; twenty cubic feet to the ton.

The proportion of mineral matter in the shale is usually about 73 per cent, and sometimes as high as 80 per cent. The various oil shales exhibit marked differences in the yield of oil and sulphate of ammonia. The richer shales yield about thirty gallons per ton and in some cases as much as forty gallons, but the high yield is usually obtained at the expense of the solid paraffin and the quality of the heavy oils. The inferior shales yield about eighteen gallons of oil per ton, but a much larger amount of sulphate of ammonia, (from sixty to seventy pounds).

The total quantity of crude shale oil produced in Scotland during 1892 to 1894 is as follows;—

	Gals.
1892	44,238,280
1893	45,725,841
1894	47,693,458

Taking the figures for the output of shale for the latter year:— the yield of oil per ton of shale is only twenty-four gallons.

The thickness of the oil-bearing shale bands mined in Scotland, according to the same author, is as follows for the eight principal seams:—

Dam or Raeburn shale	2½ to 3 feet.
Mungle or Stewart	2½ to 3 "

The Grey shale, thickness not stated, thin seams only.

The Fell shale, richest of the Scotch shales, produces from thirty-six to forty gallons crude oil, and yields from eleven to fourteen pounds amm. sulphate by the Henderson retort and from twenty-five to thirty-five pounds by the Young and Beilby retort.

The Wee, the Big, the Wild and the Curly shales, followed by the Broxburn shale which averages five and a half feet in thickness, produce twenty-eight to thirty-three gallons oil and from sixteen to twenty pounds amm. sulphate by the first, or twenty-six to thirty-two by the latter process.

The Dunnet shale, from six to sixteen feet thick, yields from fifteen to thirty gallons crude oil per ton.

The Barrack shale, average thickness of ten feet. Beneath this are the Pumpherston shales, which comprise the Jubilee, about eight feet, the Maybrick of six feet, the Curly about six and a half feet, the Big Plain eight and a half feet, the Wee Plain four and a half feet. Of these the Curly shales yield ten gallons crude per ton and sixty to seventy pounds amm. sulphate; and the average yield of the Pumpherston shales is sixteen to twenty-two gallons crude with twenty-five to thirty-five pounds amm. sulphate to fifty to sixty pounds according to the process employed. The percentage of contained oil is also said to vary considerably in different parts of the workings. Most of these shales are now taken from considerable depths, some at least from 1,200 feet below the surface.

It would, therefore, appear from a comparison of the several seams in the two countries, both as regards quantity of contained oil and thickness of shale beds, as well as the facility of mining in New Brunswick, that the latter should have a marked advantage as regards general development.

The thick oil bands of the Albert shales are found in the eastern area at Taylorville on the Memramcook river, from which place considerable quantities were shipped forty or more years ago for distillation under the old process. They are found also near St. Joseph college; at Bellevue, on the east side of the Petitcodiac river opposite Hillsborough and at Dover; at the Albert mines; on the east branch of Turtle creek in Baltimore; and on the West branch two miles west. They also appear in the Elgin area at Mapleton. In all of these places the oil shales outcrop and can be readily mined and there is a general resemblance throughout; but on the West branch of Turtle creek the oil-shale is of the grey variety instead of the black. At the Albert mines the dumps from the mining of the albertite are very large, aggregating some 120,000 tons, and these contain a large percentage of albertite, which was thrown away in the early days of the working, so that for distillation there is a very large amount of very rich material already at the surface. The locality is directly on the line of railway.

For many years borings have been made on these shales for oil. These have been sunk principally in the area between the Petitcodiac and Memramcook rivers, at Dover on the west and near St. Joseph college near Memramcook. The first attempt at boring in the shales appears to have been made about fifty years ago, the exact date not being obtainable. The hole was put down near the college, but though some traces of a black oil were obtained the results were not satisfactory and the borings were soon discontinued. Some twenty years later other attempts were made and several holes were sunk, some of which are reported as reaching a depth of over 1,000 feet and one is said to have been carried down for 2,200 feet. In this oil, in small quantity, was reported at 1,050 feet, but the attempt was abandoned at the depth stated with only small shows of oil and gas, and in none of the holes was sufficient success met with to warrant a continuance of operations. About six years ago a new company began a systematic search in order to settle the question of the occurrence of oil in economic quantity, and a number of holes were bored both near the college and at Dover, as well as on the west side of the Petitcodiac river opposite. The borings were suspended at the close of 1904, in all some seventy holes being sunk, of which about twenty were near the Memramcook river, about forty-five at Dover and vicinity, and four or more in Albert county opposite, with several others whose location is not clearly indicated, making a total of seventy-six wells.

Most of these were sunk to depths of 500 to 800 feet, but one near Dover was carried down to a depth of 3,000 feet. While many of the wells proved to be barren, quite a number have produced oil in small quantity. Of those near the college practically 50 per cent are producers on a small scale, and are being pumped at intervals from a central station. The yield is exhausted in about four to five hours, and the amount obtained from the pumping is said to be about nine barrels weekly from eleven wells, but this contains a certain amount of water also. In the Dover area twenty-one wells are pumped for six days in the week with a stated pumping average of sixty barrels of thirty-five gallons capacity monthly. Here also the flow ceases in about five hours, the contents of the wells being then exhausted. In the deep boring neither oil nor water is said to have been found.

It will be seen from these results that the amount of oil as yet obtained is insufficient to pay the cost of extraction. From a study of the shales it is difficult to find sufficient data to warrant the statement that they will ever become great producers of oil by boring. The fact, clearly established, that the whole body of the shales, with their interstratified hard bands of sandstone and thin limestone, is highly tilted and faulted is opposed to this supposition of a great producing oil-area, and the conditions are entirely different from that found in all the producing oil fields of the world. The finding of small quantities of oil in some of the wells may be explained by the hypothesis that such oils reach the boreholes through lines of fault or by seepage in some way, since in none of these has there yet been found any indication of a subterranean oil reservoir, nor is it reasonable to suppose that in so broken a mass of sediment such a reservoir can exist which might ensure a permanent and large supply.

In this respect these shales are similar to the rocks found in the great so-called oil-basin of Gaspé, where hundreds of thousands of dollars have been spent during the last twenty years and many holes have been bored over a large area, some of which reached a depth of 3,700 feet. As in New Brunswick, small quantities of oil were obtained by pumping from some of the holes, but after a short time the production of the oil ceased. These Gaspé explorations ended several years ago. Here also the strata while practically of the same horizon as those of New Brunswick or Upper Devonian, were tilted and faulted, and there were a number of well defined oil springs which were found near the line of the faults. Similar experiences were met with in similar borings near Lake Ainslie in Cape Breton and in Newfoundland on the west coast.

Of most of these borings no log has been furnished this Department and the thickness of the shale formation cannot therefore be indicated, but in some of the earlier holes it would appear that the drill passed through the bituminous shales and reached a series of red rocks at a depth of 550 feet, especially in a well bored a mile north of St. Joseph college, so that in this case probably the underlying red beds of the Devonian were reached. In regard to the deep well no log is available and it cannot be said what were the bottom rocks. Quite recently a new series of borings has been commenced in the Dover area.

GRAPHITE.

This mineral exists in but small quantity in the province as compared with the large areas of graphite bearing rocks which occur in Ontario and Quebec. Its occurrence as graphitic shale associated with crystalline limestone and diorite, near the Suspension bridge over the St. John river in St. John city, has been long known, and mining has been carried on at intervals for a number of years. While the separated graphite was not of the best quality, it was found to be suited for foundry facings, but the industry has never assumed large proportions, owing, probably, to the limited extent of the deposit. An analysis of the mineral made in this Department from samples obtained in 1878 gave as follows:—

Graphitic carbon..	48·775
Rock matter..	50·058
Hygroscopic water..	1·167
	100·000

At present mining has been discontinued at the original spot, but another outcrop occurs in a limestone cutting with shales along the side of Douglas avenue about a fourth of a mile east of the bridge, from which a small quantity of the shale has been taken.

The presence of this graphite deposit was first recorded by Dr. A. Gesner in 1840. Some years after mining was commenced, and in 1853, it is reported (M. H. Perley) that 89,936 pounds were exported, but the mine evidently closed down shortly after that date. It was reopened again in 1868 by Mr. Garrett, and the return of output for 1869 taken from the statistics in the Geological Survey report for 1871-72 is 6,000 barrels, valued at $12,000. No further returns were received from this property and mining seems to have been suspended for a time.

From Professor Bailey's report on the Mineral Resources of New Brunswick, 1897, it would appear that mining operations were resumed for a short time. A little later, probably about 1872, work was again commenced on this property, by Mr. S. S. Mayer, of Carleton, at a point about 600 yards east of the river, on the land of Messrs. Hazen and A. E. Botsford, but after the extraction of a few tons the location was sold to parties in the United States. The works were closed down shortly after, but later another attempt was made by Mr. W. F. Best and others to revive the industry, at a point about 200 feet east of the Mayer location. At this place the graphite was concealed at the surface, but on sinking a shaft it was struck in small quantity, showing at a depth of about fifteen feet. This area was regarded as a continuation of the deposit seen on the Mayer place, and the graphite is reported by Mr. H. Brumell, at that time on the Geological Survey staff, who examined the district in 1890, as occurring at the contact of crystalline limestone with a trap dike. Where first struck, at eight feet from the surface, the bed of graphitic shale had a thickness of only about two inches, but this rapidly increased and in the shaft it reached a width of eight to ten feet at a depth of fifty feet. A mass of trap with a thickness of two feet, which extended for fifty feet along the deposit, was struck at a depth of thirty feet from the surface. The dip of the hanging wall is to the south at an angle of 55 degrees. The graphite is associated in places with pyrite which breaks away readily and leaves the graphite comparatively pure. The output is said to have found a ready market at $7 per ton.

Small deposits of graphitic shales are found in Pisarinco peninsula, one at Mill creek on the east side which is worked to a small extent, the other near the mouth of Frenchman creek on the east side of Musquash harbour. At Little Lepreau, also, on the north side of Belas basin, graphitic shales occur which were at one time mined for fuel but which seem better fitted for some of the uses of graphite, resembling similar deposits in Massachusetts, where they are utilized for this purpose. Similar shales are found at Musquash on the property of Mr. Clinch.

A deposit of graphitic shales on Thorne brook in northern Kings county was opened some years ago, but was soon after abandoned.

Other occurrences have been noted in Charlotte county, but of these none have ever been utilized and it is doubtful if they would repay the cost of mining.

PEAT.

Peat is found in large bogs at many places throughout the province from north to south. They have been specially studied by Drs. R. Chalmers and W. F. Ganong. No attempt has apparently ever been made to utilize these bogs as a fuel supply, but some years ago a bog situated near Spruce lake, a few miles west of St. John city, was opened up by Mr. W. F. Todd of St. Stephen, preparatory to the manufacture of moss litter for which it was well suited. After a series of experiments a plant was put in operation which is said to have manufactured the raw peat moss from its original state, saturated with water, into a high grade finished article of litter in a few hours, but unfortunately the buildings were destroyed by fire in 1895 and the industry has never been revived.

In Ontario and Quebec experiments have been carried on for a number of years to manufacture the peat underlying the surface moss into a compressed fuel in the form of briquettes. These efforts have been attended with a certain amount of success, and the demand for the finished product is in excess of the available supply. As yet, however, the industry has not assumed large proportions; but it is doubtful, in view of the supplies of coal from the mines of New Brunswick and of Nova Scotia, whether the manufacture of peat fuel in these provinces will ever reach sufficient proportions to make it a competitor with the supplies of coal proper. Lists of the bogs in New Brunswick are given in the Report by Dr. Chalmers, G.S.C., Vol III., 1887-88.

LIMESTONE.

Limestone is found at many widely separated points throughout the province. Owing to the limited local demand and the practically prohibitive duty against the import of the manufactured article into the United States, the industry, which some years ago reached large proportions from the burning of lime around the city of St. John, has languished, although the occurrence of limestone of excellent quality and in large areas around that city presents admirable facilities for the manufacture of the finished article at the lowest possible cost of production. The importance of this industry can be seen from the statement of the figures for export at different dates. Thus in 1881 the number of barrels shipped to United States ports was only 3,644 of the value of $1,822, while in 1890 it amounted to

286,584 barrels valued at $143,292. Since then the industry has declined, the value for 1897 being only $15,634. The figures of production for the last few years are not available in this Department. The great competitor with the St. John line in the United States market is Rockland on the east coast of Maine.

At present the principal quarries are operated near St. John and owned by Stetson and Cutler, Purdy and Green and by W. Lawlor and Son, the last at Brockville. Of other quarries once in operation, but at present closed down, are Messrs. I and F. Armstrong on Green head, first opened in 1828; Miller and Woodman, Green head; W. D. Morrow, Narrows of St. John river; and Mr. Stevens of South bay.

A peculiarity observed in all these quarries is the large number of dikes of epidotic green diabase which cut the limestone in all directions and often seriously interfere with the quarrying. Some of the larger dikes have masses of the limestone caught in the igneous mass, and the alteration of the limestone is most pronounced as the dike is approached.

Analyses of the limestone from several of these quarries have been made by Dr. Hoffmann of this Department with the following results:—

The quality of stone is excellent throughout.

I and F. Armstrongs' quarry, Green head.

Rock a dark bluish-grey, fine crystalline, massive, holding occasional specks of iron pyrite: after drying at 100 C,—Hygroscopic water = 0·09 per cent.

Carb. lime		95·60
Carb. magnesia		0·44
Carb. iron		0·13
Alumina	0·11	
Sol. silica	0·16	4·27
Insol. min. mat	3·54	
Organic matter	0·46	
		100·44

Limestone from Stetson quarry, Indiantown.

Light and dark bluish-grey, banded, somewhat coarsely crystalline and massive; after drying at 100 C., Hygroscopic water = 0·04.

Carb. lime		99·05
Carb. magnesia		0·88
Carb. iron		0·13
Alumina	0·01	
Silica soluble	0·9	0·26
Insoluble mineral matter	0·14	
Organic matter	0·02	
		100·24

W. Lawlor and Son's quarry, Brookville.

Bluish-grey, somewhat coarse crystalline, massive.

After drying as before—

Carb. lime		98·39
Carb. magnesia		0·71
Carb. iron		0·05
Alumina	0·02	
Silica soluble	0·04	1·19
Insol. min. matter	0·82	
Organic matter	0·31	
		100·34

Crystalline limestone is also found in Pisarinco peninsula, on the east side along the shore to the south of Spruce lake and on the west side from Frenchman creek to Black beach. At this latter place the quantity is large, the quality excellent, and there are good shipping facilities, which would obviate the hauling necessary for much of the St. John lime. Abundance of wood for burning is found in the immediate vicinity. Farther west, crystalline limestone occurs on the south side of Belas basin, Lepreau, and in rear of Musquash village, but the outcrops in both these places are local and the formation cannot be traced far across country.

Other limestones, sometimes crystalline, are found in several geological formations. They have occasionally been utilized locally.

The largest of these so utilized is in Carleton county in Brighton, of Silurian age, which has been burned to some extent. In Albert county the Lower Carboniferous limestones were at one time burned for lime quite extensively, but though furnishing a good quality of the burned material the competition with the large kilns of St. John was against the continuance of the industry. Some of these Albert limestones are highly bituminous and it has been suggested that they might be used in the matter of sidewalk construction in towns. No attempt has ever been made in this direction.

GYPSUM.

The quarrying, calcining and export of gypsum is at present one of the leading industries in the province. The principal works and quarries now operated are situated at or near Hillsborough, in Albert county, a short distance from transport by the Petitcodiac river and by rail communication on the Salisbury and Harvey railway.

The raw material is found in great abundance as a part of the Lower Carboniferous formation both in this province and in Nova Scotia. Both the hydrous and anhydrous varieties occur, the latter, however, being of but small commercial value at the present time. The gypsum beds are usually found overlying a series of red conglomerates and limestone and are usually overlain by, and sometimes contain, beds of red marly shales. It varies in quality greatly, sometimes being white and clear, translucent, in which case it is styled alabaster; at other places it is crystallized in the form of selenite; sometimes it is deeply coloured, reddish or dark grey. The gypsum, while ordinarily massive, sometimes presents a well-banded or stratified appearance, lying in nearly horizontal beds of various colours and of varying thickness and purity, and the prevalent tints being white or grey. The so-called soft plaster alternates in the quarry with beds of the anhydrous variety, the contact between the two being usually sharp, and this necessarily adds greatly to the cost of extraction; while frequently the deposits are covered with heavy masses of red clay and soil which have to be removed in the mining. This alteration of soft or hydrous and hard or anhydrous plaster in the same beds is somewhat difficult of explanation, the transition being often so sharply defined. The former by analysis contains calcium 32·5, sulphuric acid 46·6, water 20·9, but the mineral is often quite impure owing to the presence of organic matter, clayey material, iron compounds and the carbonates of lime and magnesia. The different colours seen in rock plaster are apparently due in large measure to these impurities. The hardness is 1·5 to 2·0, being easily scratched with the finger nail, thus distinguishing it from certain forms of limestone. Anhydrate has the same chemical composition except that it contains no water of crystallization and by the absorption of water this variety changes to the soft or hydrous variety; it is probably in this process of water absorption in nature that the alteration of the hard plaster to the soft is accomplished. Gypsum is also frequently associated with rock salt, and while this association has not been clearly recognized at any of the quarries worked in Albert county, the presence of salt springs which are found in the Kennebecasis valley, where they have been utilized for the manufacture of salt, is recognized in close proximity to well-known gypsum deposits which outcrop in this area.

Gypsum may be formed in two ways, either by the action of sulphuric acid or carbonate of lime, as is done in the laboratory, or by being deposited by evaporation. The Hillsborough deposits, according to the late Sir William Dawson, have been produced by the former method.* Limestone is very abundant in the Lower Carboniferous formation, and the sulphur could be derived either by the decomposition of iron pyrites or the decay of organic matter. On the other hand, the beds are usually interstratified with shales, sandstone and limestone which have been deposited in arms of the sea or in lake basins. The water, with salt and gypseous matter in solution, has, owing to evaporation, reached a sufficient degree of concentration to prevent the growth of organisms, since traces of these are rarely found in the gypsiferous formations, while the presence of iron oxide usually imparts a red colour. Thus in process of time the gypseous matter has formed beds of plaster sometimes of great thickness.

Analysis of the plaster from the Hillsborough quarries made by A. A. Breneman, N.Y., is as follows:—

Lime	32·45
Sulphuric acid	46·38
Water	21·05
Silica	0·25
Iron	trace
Magnesia	trace

The Hillsborough deposits were known and worked to some extent sixty years ago, but in 1854 the quarries in rear of the village were acquired by Mr. C. Tompkins and the shipment of the raw material to the mills in New Jersey was commenced. Later, a milling plant for calcining the crude output was erected near the point of shipment on the Petitcodiac river, and the manufacture of plaster of Paris was carried on there. For some years the output as excluded from the markets of Ontario and Quebec, owing to the cost of transportation, but the opening up of the Intercolonial railway in 1876 allowed access to these provinces and a very large business is now carried on in this direction. Great quantities of the crude are still sent to the United States from Hillsborough in addition to the shipments of prepared plaster. Some idea of the growth of the industry may be obtained from the following figures, furnished by Mr. C. J. Osman, the managing director of the Albert Manufacturing Company. Thus, in 1877, the total sales in Canada were about 8,000 barrels, while in 1897 the Canadian trade had increased to 38,000 barrels; the shipments of crude gypsum to the United States increased from 5,000 barrels in 1877 to 59,334 in 1897 and in 1905 the figures were, mined 137,551 tons, for calcining 15,000 tons; the balance of 122,551 being shipped as crude.

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* See "Gypsum Deposits of New Brunswick," by L. W. Bailey, Roy. Soc. Can. Trans. 1906.

Up to the present time the anhydrite has but little commercial value, being unsuitable for the manufacture of plaster of Paris. A certain amount is ground, however, and used, under the name of 'terra alba,' as a paper filler. It is equally adapted for land plaster as a fertilizer as the hydrous variety, and considerable quantities are now exported from the quarries in Nova Scotia, presumably for this purpose.

The price of crude gypsum delivered at the wharf in Hillsborough varies. For the lower grades, suitable for land plaster, including the discoloured rock, the price is 60 cents per ton; while for the higher grades used for the manufacture of calcined plaster it ranges from $1 to $2, and for the selected grades $2.50 per ton.* The quarries at Hillsborough are connected by steam road with the plaster mill and with the wharf at the Petitcodiac river.

Other large deposits of gypsum occur in Albert county, several of which are quarried. The Hillsborough Plaster Company located on Demoiselle creek took out about 5,000 tons in 1905, of excellent quality, and other quarries in the southern part of the county, as at Hopewell hill and Shepody mountain, have also been worked to some extent, but the figures of output are not to hand. Plaster also occurs in New Horton but has not as yet been opened up to any considerable extent.

The Albert Manufacturing Company is also opening additional deposits, one at Pink ledge, about one mile north of the end of Cape Maringouin on the east side of Shepody bay, where there is a deposit of large size and excellent quality from which shipments have already been made, and also on a deposit occurring at Martin head on the shore of the Bay of Fundy in eastern St. John county. In Westmorland county, two and a half miles west of Petitcodiac station, a deposit of gypsum, said to be forty rods in width and traceable for one mile, is found, in which a body of selenite occurs with a breadth of eight feet. This is also controlled by the Albert Manufacturing Company, but has never been largely mined. In Kings county quite extensive deposits are found near Sussex and in Upham near the road from Sussex to Quaco, from which about 500 tons were quarried during 1905.

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* Much of this information is taken from an excellent article prepared by Mr. Osman for Dr. Bailey's report, 1899.

In Victoria county, at Plaster Rock, heavy beds of somewhat impure gypsum associated with shales of the Lower Carboniferous formation occur. These are now connected by rail with the Canadian Pacific railway along the St. John valley. The mineral is well adapted for land plaster, and a mill has been erected in which it is ground and thence shipped in considerable quantity to the farms along the St. John river, as well as to Aroostook in Maine where it is highly esteemed as a fertilizer. During the season of 1906 work at these quarries was mostly suspended.

The total shipments of plaster from the province for 1905 aggregated 146,030 long tons in crude and manufactured, of a value of $232,586. Of these Plaster Rock shipped 819 tons, part of which was ground, the whole being used for land plaster.

One large element of expense in quarrying the plaster at certain places is the very heavy body of red clay which frequently overlies the mineral, and which is often allowed to fall into the pit instead of being removed by stripping before quarrying. This would seem to be an expensive way of removing such large masses of waste material. Another large item of expense in some of the quarries is the large percentage of anyhydrite which is practically of no value.

Granite, diorite, &c., occur over large areas and have been quarried for building stone, monumental work, &c., for more than thirty-five years.

GRANITE, &C.

Of the granites, both red and grey and the so-called black varieties occur. In age these are comparatively recent, since in many cases they cut rocks as new as the Devonian sediments, corresponding in this respect with certain similar granitic rocks of Nova Scotia.

Among the largest of these granite masses is that found in Charlotte county, which extends across the county from the St. Croix river northeast almost to the St. John river. The rock is generally red, but sometimes passes into grey. In different parts of the area are large masses of the black variety which is in reality a mica-diorite. This is found in the western area north of Bocabec, near the Magaguadavic river; and eastward near Welsford on the line of the Canadian Pacific railway. This rock consists of labrador feldspar and hornblende with some magnetic iron; it takes a good polish, is very hard and tough, and is as a consequence a more difficult rock to dress and to finish properly.

The principal granite quarries in the province are situated near the village of St. George in Charlotte county and along the Magaguadavic river for some miles north. The principal quarries at present in operation are owned by:—

Milne, Coutts and Company.
Epps, Dodds and Company.
O'Brian and Baldwin.
Tayte, Meeting and Company.
Utopia Granite Works (H. McGrattan and Son).
Messenette and MacDougall.

The granite industry at this place was begun in 1872, by a New York company, and a plant for cutting and polishing was erected, which, however, in a few years, suspended work. Subsequently (1881), Milne, Coutts and Company acquired this plant and have continued the business to the present time. Exceptional facilities are afforded here for the manufacture of the stone owing to the supply of water for power furnished by the falls on the river, and the rough material can be brought from the quarries to the mills, either by scows down the Magaguadavic river or by teams.

The amount of rough stone produced at these quarries varies according to the demand. There is also a certain amount of stone known as 'black granite' brought from outlying points and at the works blocks of grey stone from the St. John River quarries (Spoon island) are dressed and polished.

The Spoon Island quarries are in a spur of granite which comes to the St. John river about three miles south of the village of Hampstead, opposite the lower end of Spoon island. The stone is a grey granite of excellent quality, and two firms are here engaged in quarrying, viz.: Allan Appleby and D. Mooney and Son. The output during the past season was about 2,500 tons.

Of the 'black granite' the output from the quarries near Bocabec in 1905 was about ninety tons.

In the York County belt, opposite the mouth of the Sheogomoc river, are the works of the Southampton Marble and Granite Company (Oldham Bros.). The output for some years has been used largely for monumental work, but no returns have been received by this Department. In the northern part of the province no granite quarries are now operated, though a good quality of rock is found at several places, as along the lower part of the Nipisiguit river.

Among other rock formations suited for stone as ornamental work but small indications have as yet been found in the province. The crystalline limestone of St. John does not appear to be very well adapted either for building or decorative work, while the small portions which are slighly serpentinous are equally unsatisfactory. In Ontario and Quebec, where serpentinous limestone and breccia occur in large quantity, but little use has ever been made of them. The serpentine of Pisarinco, which has sometimes been alluded to. has been worked out, it consisting merely of a pockety deposit with small threads of crysotile. That of Frye island and of Musquash is usually too much shattered to furnish blocks of large size, and is better adapted for lime burning, while the felsite of Chamcook, while furnishing beautiful hand specimens that take a fine polish. cannot be obtained in blocks of size sufficient for decorative purposes.

FREESTONE, MILLSTONE AND GRINDSTONE.

The great extent of the Millstone-grit formation in this province, with its widespread formations of sandstone and grit, furnishes an abundance of material for building and other purposes. At many places the quality of the stone, usually grey, is eminently adapted for building material, for which purpose very large quantities have been quarried and extensively shipped, as well as used locally. Some of the grey beds have a fine grit that especially adapts them for use as grindstones either for metal or for pulp wood.

For years a number of these quarries were in operation in southeast New Brunswick in the counties of Albert and Westmorland. Much of the grindstone was taken from ledges on the beach which were exposed at low water, the great rise and fall of the tides on this part of the coast, from forty to fifty feet, rendering it possible to extract the stone and then to float it to high water mark as the tide came in. At the extensive quarries on Grindstone island, and at Mary point, both grindstone and building stone were quarried on a large scale some thirty-five to fifty years ago. On the mainland at the Budreau and Rockland quarries large quantities were raised for both purposes but the large amount of waste and the increased cost of extraction became such that they have both closed down for the present, and with the exception of a few grindstones, which are taken out at Rockland, no work is now being done at either of these localities. At the present time the only quarries working in eastern New Brunswick are in Westmorland county at Sackville and at Woods point about three miles south. The beds which lie nearly horizontal are composed of a brownish sandstone of Upper or Permo-Carboniferous age. Mills have been erected at both places for sawing and dressing the stone. At Sackville the output is a beautiful stone largely used for building purposes and occurring in blocks of any required size. The quarry is owned by Mr. Charles Pickard and turned out, last season, about 3,000 gross tons, valued at $12,000, besides 1,000 tons rubble. At Wood point, the quarry, owned by the Reid Bros., has, for the last eight years, mainly produced grindstones, the principal markets for which are in the United States and eastern Canada.

In the northern part of the province extensive quarries in grey stone were in operation for many years, especially in the Miramichi district where beds of the peculiar grit abound. At the present time all these old quarries are closed and the only one now worked is at the terminus of the Indiantown branch railway on the Miramichi, about twenty-one miles west of the bridge (Intercolonial) across the river. One of the most important of the old quarries on the lower Miramichi near Newcastle was the French Fort or Fish quarry, from which the stone for the Langevin block in Ottawa was taken. This stone is an olive green, works readily, and hardens, like many freestones, on exposure to the air.

The quarry at Indiantown is very similar in character. The formation is Millstone-grit and plant bearing beds are found between the beds of massive sandstone. The stone is also olive, and occurs in a high bluff which is easily reached, the beds ranging in thickness from sixteen inches to eight feet with a lower bed of over ten feet, the bottom not being reached. The layers are practically horizontal and regular and the stone dresses readily with a sharp edge. This quarry was opened about eight years ago. The quarry is equipped with steam derricks. The quarry is owned by W. Hood and Son of Montreal, and the output for the season of 1905 was about 20,000 feet of rough dressed stone valued at $8,000, and 700 tons of rubble. The output is hindered occasionally by the scarcity of labour. Part of the output is admirably suited for pulp stones of which twenty-five were made weighing about two and a half tons each. The stone finds ready sale in Montreal and the western cities of Ontario.

On the south side of Chaleur bay several quarries producing excellent grindstone are in operation. Of these the principal one is owned by Joseph Reed and Company, and has been in operation since 1844 when it was opened by Messrs. Sprague of Boston. It was taken over by the present firm in 1852.

The beds of grindstone grit have a thickness of about twenty-one feet, and this formation is overlaid by chocolate-brown shales. The beds are almost horizontal or dip southeast at an angle of one to two degrees. The quarry is opened on the beach and the water is kept out by a well-built dike, and by the aid of steam pumps. It is operated for about five and a half months, but is flooded in winter in order to preserve the stone from the action of frost.

In addition to grindstones of all sizes a considerable quantity of scythe and other small stones is made. The yearly product is about 2,700 tons. Other quarries are found in practically the same reef which shows along the shore for some miles. These are Noel's at Clifton and a quarry at Grand Anse from which both grinding and building stone are produced. The latter was employed in the construction of the new Roman Catholic church at that place. Other small quarries are found, opened for local purposes apparently, but from which no returns are made to this Department.

Among these may be mentioned a quarry at Scotch settlement, at the head of Shediac river, known as McSweeney's, the output of which was used in the Roman Catholic church, Moncton; at Cocagne at the crossing of the Moncton and Buctouche railway, the stone being of both purple and grey varieties, and used in the Young Men's Christian Association building at Moncton; and a quarry along the line of the Canadian Pacific railway between Fredericton and Fredericton Junction where the stone for the provincial Parliament buildings was obtained, the output also being in two shades, grey and purple.

SLATES.

No beds of slate, of value sufficient to warrant the expense of opening, have as yet been found in the province, nor is there any indication that such beds exist, though the slate formation as a whole is of large extent. The great cost attendant on opening a quarry of slate, even in very favourable circumstances, and the comparatively small demand for the manufactured article, are such as to render competition with the large quarries of eastern Quebec or of Wales practically impossible.

Flag stones and hearth stones can be found at several places, but the demand for the former has greatly fallen off for sidewalks owing to the use of granolith or asphalt, while in the absence of blast furnaces there is at present no local demand for the latter. These were at one time obtained from red beds along the Tobique and Becaguimec valleys, and were used locally while the Woodstock iron furnaces were in operation.

CLAYS.

Both brick and fire clays occur, the former being used locally to some extent, but no attempt has yet been made to utilize the latter, which occurs in connexion with the coal seams both at Minto and at Beersville. Brick yards are quite numerous about St. John, of which probably the principal are owned by Messrs. John Lee and Company, with yards on the east side of Courtney bay near the mouth of Little river. The output from these is about 2,000,000 common brick, 100,000 pressed and 10,000 drain tiles yearly, but in 1905 the common brick amounted to 2,800,000. Messrs. D. Mooney and Son also operate extensive brickyards at Fairville, the figures of recent output not being to hand.

The yards at Fredericton, owned by Messrs. Ryan and Son, in 1905 produced 1,400,000 common brick and 20,000 tiles. Those at Fairville, owned by Messrs. Mooney and Son, produced about 1,000,000 common brick.

Other yards are found at Bathurst, Chatham, Lewisville, Moncton, Newcastle, St. Stephen, Sussex, Marysville, Woodstock, &c., but of these no official returns are available. Recently a new deposit of clay marl was opened on the bank of the Salmon river about three miles from Harcourt by Mr. Van Buskirk and the first kiln was being prepared for burning in August last, 1906, the results of which have not been learned.

SILICA.

Silica and infusorial earth have been known for many years. Of the latter, deposits are found in the beds of several lakes, as in Pollet River lake and Pleasant lake in Kings county, and in Fitzgerald lake a few miles east of St. John. Of these the Pollet Lake deposit has to some extent been worked, the lake having been drained several years ago, and preparations are now being made to ascertain its commercial value. Fitzgerald lake was also drained and is being carefully tested, but only small shipments have as yet been made from either of these localities. Though of good quality the distance of several of these deposits from transportation facilities is such as to entail considerable expense in shipment of the raw material. This mineral is of organic origin, thus differing from ordinary deposits of silica.

Silica proper occurs in Charlotte county near Black harbour and has been utilized to some extent in the manufacture of polishing-powder, scouring soap and for fillings of wood, &c. The deposit is described in Dr. Bailey's report as occupying from one to two hundred acres with a thickness of about ten inches in places. It is practically a fine silt. Analysis by Messrs. Ledoux and Ricketts of New York is as follows:—

Silica	72·65
Alumina	17·93
Sesquioxide of iron	0·57

—with small quantities of lime, and magnesia and some contained water. This property is now owned by Mr. G. W. Ganong and others of St. Stephen.

MINERAL PAINTS.

Only few deposits of this substance are known and none appear to be utilized, or at least to but a small extent. A brown-red ochre is found near Edgett landing in Hillsborough, Albert county, which burns to a fine red powder, but the quantity of this mineral has never been ascertained.

On the Northwest Miramichi near Chaplin island the slates of the area are covered with a deposit of red ochre which fills the seams in the underlying rocks. It has been regarded by some as an iron ore of economic value, but the quantity is too small to be of importance, and it appears to be rather an exudation from the bank of red clay which covers this part of the country. No other occurrences are recorded.

MINERAL SPRINGS.

Saline springs occur at several points in the valley of the Kennebecasis river as at Plumweseep, four miles north of Sussex; at Salt Springs brook in the parish of Upham; to the north of Anagance near the head of Smith creek; and on the Tobique in Victoria county.

At the salt springs near Sussex the manufacture of salt by evaporation has been carried on for many years, though on a small scale, the output rarely exceeding 150 to 200 barrels per year. It is regarded as of special value for domestic and dairy purposes and sells readily for $2 to $3 per barrel. The evaporating plant is small and is run only during warm weather, though the supply of brine from the spring is sufficient for a much larger and continuous plant. It would seem possible with a well constructed modern plant to maintain an industry at this place equal to that in western Ontario, where the manufacture of salt by evaporation has assumed large proportions. In Ontario also the ground was well tested by boring, and heavy beds of salt were found at depths of more than 1,000 feet from the surface. In New Brunswick but little attempt has been made in this direction though a couple of holes were sunk some years ago, but these were merely shallow wells, the deepest recorded being only 330 feet. In view of the fact that the gypsums are abundant in some parts of this area it would seem advisable to thoroughly test the district with several holes sunk to a considerable depth to ascertain whether underlying bodies of salt do not exist in this part of the province.

Analysis of the Sussex brine from the Salina spring near Upham is as follows:—

	Per Mill.
Potassium chloride..	19·963
Sodium chloride..	1293·648
Magnesium chloride..	22·315
Sulphate of lime..	268·212
Sulphate of magnesia..	11·336

The strength of the Sussex brine is given at 20 per cent. The manufacture and shipment of mineral waters has now reached considerable proportions. In Sussex on Mr. S. H. White's place a fine well was obtained (Artesian) by boring, the flow being through a four inch pipe, and a large plant for the manufacture of mineral waters of several kinds has been erected and is in very successful operation. The analysis of this water is as follows:—

	Grains.
Potassium chloride..	0·21
Sodium chloride..	2·10
Sodium carbonate..	25·35
Carbonate of lime..	1·47
Silica..	1·05
	30·53

Traces of hydrogen sulphide are found in this water and can be detected both by smell and taste. The waters of Upham are also quite extensively bottled under the name 'Mahpu,' as also the waters from a spring in Havelock north of Petitcodiac, Kings county. No returns from any of these springs have been sent to this Department, though the industry promises to become a somewhat important one in a comparatively short time.

ROAD MATERIAL.

The supply of a good road material for use in city streets, as also in the country, has always been an important problem. For many years the softer rocks such as limestone, sandstone &c., were employed, but these speedily wear out and leave great quantities of dust in fine weather and of mud when it is wet.

In cities like Fredericton and St. John the presence of masses of igneous rocks has been recognized. In the latter city the green diabase found with the limestones, and the granite at many points around the city, should furnish an unlimited supply of good road material, while near Fredericton the basalt of Clark mountain is also available, and easy of access.

CONCLUSIONS.

It will be seen from the foregoing remarks on the various minerals found in this province that the actually profitable mining is confined to the non-metallic minerals at present comprising the coal, gypsum, building-stone, shale deposits, clay, &c., and sufficient has been said to show that in most cases these industries can be largely developed under proper attention to business requirements, and worked at a profit. As to the ore-deposits proper, but little can at present be said in their favour. Large sums of money have been spent in futile attempts to develop certain of these, much of which it is only fair to say might have been avoided had a proper examination of the territory by competent and disinterested persons been made. Of these large expenditures it is safe to say that only a very small proportion has been returned to the investors.

In the copper industry all attempts at mining have been disastrous, owing principally to the small amount of the mineral itself in all the occurrences as yet known, and to the broken nature of the deposits, since although there have been a number of occurrences of good ore, in no case have these been sufficiently extensive to make profitable returns on investment. The silver and galena ores are too poor in silver to render its extraction profitable, especially in view of the small size of the lead veins. The manganese ores were for some years worked profitably owing to the finding of large pockety masses of excellent quality, but of these the largest deposits and those of the highest grade, have long been exhausted apparently, or at least but small attempts have been made to find a further continuance of the same, while the uncertain pockety nature of the occurrence renders more difficult its profitable exploitation. The new discoveries in iron appear to indicate a possible profitable field for investigation if the cost of transport is not excessive. As regards the bituminous shale industry and the associated albertite there appears to be a promising field for the investment of capital skilfully applied, though the recent investigations of these in the search for oil have not as yet given promising results.

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